

MEMOIRS OF THE GEOLOGICAL SURVEY.

SUMMARY OF PROGRESS

OF THE

GEOLOGICAL SURVEY

OF THE

UNITED KINGDOM

FOR

1898.

PUBLISHED BY ORDER OF THE LORDS COMMISSIONERS OF HER MAJESTY'S TREASURY



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PREFACE.

IN the *Summary of Progress* for 1897, which was the first of this series of Annual Statements, an introductory sketch was given of the origin and history of the Geological Survey and of the Museum of Practical Geology.

The present volume deals entirely with the work of the past year. It is gratifying to be able to report that both in the field and in the office and Museum much important and useful work was accomplished. Among the more noticeable portions of it, I may specially direct attention to the researches among the younger granites of the Highlands, particularly in the range of the Cairngorm Mountains and the Ben Cruachan group; to the detection of Corundum among the Cordierite-bearing rocks of the contact zone round the Ben Cruachan granite; to the finding of Arenig rocks, and the more precise definition of the position of the "Cambrian" rocks of the south-east of Ireland; to the numerous Cambrian fossils obtained in Skye; to the discovery of still further new fishes in the Upper Silurian rocks of Lanark and Ayrshire; to the ascertaining of a hitherto unsuspected Carboniferous outlier in Lorne; to the novel tectonic structures found to traverse the South Wales coal-field; to the remarkable evidence brought forward of the existence of a group of volcanoes belonging to the time of the Carboniferous Limestone in Somerset; to the new light thrown on the structure and probable extension of the North Staffordshire coal-field during the course of the revision of that district; to the additional information obtained regarding the complicated volcanic history of the western mainland of Scotland and the Inner Hebrides; and to the fresh data gathered from all parts of the three kingdoms respecting the successive stages of the Ice Age.

The practical applications of the work of the Geological Survey continue to be increasingly asked for both by the general public and by the various Government Departments. These enquiries however can hardly be referred to in this Report, save in general terms. They relate to water supply, building sites, mines, minerals, and many other economic or industrial questions in which a knowledge of geology is required. A brief account of them will be found in Part IV. of the present Summary.

ARCH. GEIKIE,
Director-General.

Geological Survey Office,
28, Jermyn Street, London,
17th February, 1899.

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SUMMARY OF PROGRESS

OF THE

GEOLOGICAL SURVEY

FOR 1898.

During the year 1898 several changes have been made in the staff of the Geological Survey in the United Kingdom. Changes in the Staff. MR. C. E. DE RANCE, of the English branch of the service, resigned in March last, and the vacancy thus caused was filled up by the appointment of MR. C. B. WEDD, B.A. Another vacancy, which arose from the resignation of MR. WATTS in the autumn of 1897, was last spring filled up by the appointment of MR. WILLIAM POLLARD, M.A., D.Sc.

In the Palæontological Department some considerable changes have taken place. MR. GEORGE SHARMAN, one of the two Palæontologists and Curators of the Fossil Collections, retired on 31st December, 1897. His colleague, MR. E. T. NEWTON, F.R.S., was thereupon promoted to have entire charge of the Palæontological Department, with the same rate of salary as that of a District Surveyor. Two offices were created of Assistant-Palæontologist and Assistant-Curator of Fossils. To the former, MR. F. L. KITCHIN, M.A., Ph.D., was appointed, and he entered on its duties on 12th March last. To the latter MR. H. A. ALLEN was advanced, with increase of salary. The position of the Fossil Collector, MR. J. RHODES, was likewise improved by the allocation to him of the duties of Assistant in the Fossil Department, whilst he still performs the duties of Fossil Collector.

On the Irish staff, the vacancy caused by the retirement of PROFESSOR SOLLAS in 1897 was filled in April last by the appointment of MR. HENRY J. SEYMOUR, B.A., who will conduct the petrographical work of that branch of the Survey.

I.—FIELD WORK.

The mapping during the past year has been continued in each of the three kingdoms in the several districts described in the last Summary of Progress. Its general distribution will here be briefly stated, and its detailed results will be more fully given in subsequent pages (p. 6, *et seq.*). Distribution of the staff in the field.

ENGLAND AND WALES.—In this part of the United Kingdom the energies of the service are mainly concentrated

on the revision of the counties upon the maps on a scale of six inches to a mile. Two important kinds of revision are undertaken. In one of these the superficial deposits are traced out with especial care, so as to lay a foundation for a general agricultural or subsoil map of the whole country. In the other, the various mineral districts, originally surveyed on the one-inch maps (which were the only Ordnance sheets then available), are now being mapped out on the larger scale and brought up to date. In both these revisions every effort is used to make the maps as complete and accurate as possible, and to bring them abreast of our present knowledge. Thus the revised maps of the superficial deposits include also all corrections and additions which the progress of time has shown to be necessary in the mapping of the older formations underneath, while the re-survey of the mineral fields has involved at the same time the detailed mapping of the superficial deposits of these districts.

Leicester-shire and S. Derbyshire.

The re-examination of the coal-field and surrounding country in Leicestershire and southern Derbyshire has been continued by MR. FOX-STRANGWAYS, who has surveyed $71\frac{3}{4}$ square miles of that region, and has traced 426 miles of geological boundary-lines, of which 256 related to the superficial deposits or Drift.

North Staffordshire.

The North Staffordshire coal-field and the region around it have engaged the services of five members of the staff. MR. DE RANCE's retirement made it desirable that the revision of this ground should not fall behind, but be pushed forward with all possible vigour. Accordingly MR. GIBSON, who has had considerable experience in coal-field work, was temporarily transferred from South Wales to carry on the colliery part of the revision. MR. WEDD on his appointment was stationed, under MR. GIBSON's supervision, on the red rocks and Drifts along the western border of the coal-field. On completing his working season among the Grampian Mountains, MR. BARROW was moved in the early autumn into the tract of Lower Carboniferous rocks lying to the east of the coal-field, while in like manner MR. LAMPLUGH was transferred to the ground along its southern border. MR. FOX-STRANGWAYS was placed in general charge of the revision, and from his station at Leicester was able from time to time to inspect the progress of the work. The total area in North Staffordshire thus surveyed amounts to $180\frac{1}{2}$ square miles, and the boundary-lines to 760 miles, whereof 452 represent the distribution of the various drifts.

Basin of the Thames.

The southern counties are now undergoing revision on the large scale of map. The general charge of this work is in the hands of MR. H. B. WOODWARD, F.R.S., District Surveyor. In this region it has been found desirable to accelerate the re-mapping of the superficial geology of the London District, and for that purpose to intermit for the present the prosecution of the revision of Northamptonshire so as to permit of the transference of MR. CAMERON from that county to the basin of the Thames. The original geological survey of Middlesex and the surrounding region, made upon the one-inch scale Ordnance maps, did not discriminate various superficial

deposits which subsequent experience has shown it to be of practical importance to represent separately upon large-scale maps. Thus the brick-earth and gravel were formerly grouped together, whereas it is most desirable that these valley-drifts should be carefully distinguished. For many practical purposes, such as water-supply, drainage, choice of building-sites, market-gardens, etc., the necessity for minute and accurate mapping of the superficial accumulations is now everywhere recognised. When the survey of the district is completed, it is intended to prepare and issue a colour-printed edition of the map. From the large sale of the Survey memoir on "Soils and Subsoils," it may be expected that a detailed subsoil map of the London district will be found to be of considerable general utility.

In Northamptonshire, before his transference to the Thames Valley, MR. CAMERON had last year completed the revision of an area of 20 square miles, and had traced 135 miles of boundary-lines, including 75 that related to Drift. Since he began work in Middlesex he has mapped a further area of 32 square miles and 86 miles of Drift boundaries. Northamptonshire.

In Oxfordshire, Berkshire and Buckinghamshire MR. J. H. BLAKE, from his central station at Oxford, has surveyed a total area of 51 square miles, which have comprised the tracing of 161 miles of boundary lines, 84 of these being Drift lines. Oxfordshire, Berkshire, and Buckinghamshire.

In Dorsetshire, Hampshire and Wiltshire the revision has been in the hands of MR. REID, MR. BENNETT and MR. HINXMAN. In the Southampton district MR. REID has surveyed 68 square miles, and has thus been able to fill in considerable tracts that had not been completed by MR. WHITAKER at the time of his retirement. This mapping has necessitated the tracing of 267 miles of boundary-lines, of which 179 belonged to the superficial deposits. From his station at Salisbury MR. BENNETT completed an area of about 50 square miles and mapped 165 miles of boundary-lines, including 56 miles of Drift-boundaries. MR. HINXMAN, temporarily transferred from the Scottish staff, was stationed in October in the western part of Dorsetshire, where, in the district around Maiden Newton, he revised 20 square miles and traced 74 miles of boundary, whereof 47 related to the Drift. In Hampshire MR. HAWKINS spent a short time in completing a small area of 6½ square miles, where he traced 19 miles of boundary, six of which were Drift-lines. Dorsetshire, Hampshire, and Wiltshire.

In Devon and Cornwall three surveyors have been engaged. From Plymouth as a centre, MR. USSHER has continued his re-mapping of the borders of the two counties, where he has surveyed 29 square miles, tracing 133 miles of boundaries, including 88 miles of Drift-lines. From Falmouth MR. J. B. HILL surveyed an area of 24 square miles, including 49 miles of boundary. This return would have been considerably larger had he not been disabled from field-work by continued ill-health for much of the year. MR. WILKINSON moved in October from Argyllshire to Cornwall, and from his station at Penzance, during a few weeks of field-work, mapped six square miles, with three miles of boundary-lines. Devon and Cornwall.

South Wales
Coal-field.

The revision of the South Wales coal-field has continued to make satisfactory progress. Under MR. A. STRAHAN'S supervision the field-work has been carried on by MR. R. H. TIDDEMAN, MR. W. GIBSON, and MR. T. C. CANTRILL. The total area surveyed in this region by these four officers has been $131\frac{1}{2}$ square miles, comprising 799 miles of boundary, of which 303 relate to the Drift. It should be added that this return was necessarily reduced by the transference of MR. GIBSON to North Staffordshire as already mentioned. He was absent from South Wales until late in the autumn.

The total area revised in England and Wales during the past year has been 690 square miles. The extent of boundary-lines traced has amounted to 3,077 miles, and of these rather more than half, or 1,634, have been connected with the mapping of the superficial deposits. Taking the country as a whole, each square mile of ground surveyed has involved the tracing of about four and a half miles of geological boundaries.

Ross and
Cromarty.

SCOTLAND.—The field-work has been continued in the districts referred to in the last *Summary of Progress*. MESSRS. PEACH, HORNE, and POCOCK were engaged during most of the season in the mountainous ground around Lochs Fannich and Luichart. MR. PEACH mapped an area of 61 square miles within the combined county of Ross and Cromarty, and traced 549 miles of boundary-lines. He was able to connect the surveyed area on the west side of the country with that already mapped on the east side. Thus a continuous tract of surveyed ground now stretches completely across the Northern Highlands from Skye to the Moray Firth. Besides this mapping, MR. PEACH was engaged with MR. HORNE and MR. A. MACCONOCHIE in studying sections of the Silurian rocks in the Pentland Hills, Lanarkshire, and Moffatdale, in order to procure additional material for the completion of the monograph on the Silurian Rocks of the Southern Uplands, to which more special reference will be made in a subsequent page.

In the Fannich Forest, and subsequently in Eastern Ross and around Kiltarlity, MR. HORNE mapped a total area of 50 square miles, and $189\frac{1}{2}$ miles of geological boundary. Later in the year he revisited parts of the counties of Banff and Aberdeen for the purpose of procuring fresh information in reference to a map about to be engraved, and traced there $17\frac{1}{2}$ additional miles of boundary.

After the close of the possible working season among the Ross-shire mountains, MR. POCOCK was transferred to Argyllshire to assist in completing some of the work left unfinished by MR. HILL. In the autumn he returned to the Caithness ground, on which he was engaged during the preceding year. His total area of field-work amounts to $52\frac{3}{4}$ square miles, with 319 miles of boundaries.

Glenelg.

MR. CLOUGH resumed his station at Glenelg, but immediately thereafter he met with a serious accident in the course of his field-work. Slipping on a steep slope, he so injured his foot as to be unable to put it to the ground, and he was consequently

incapacitated from field-work during the whole of the rest of the year. The progress of the mapping of the North-West Highlands has thus been materially checked by his unfortunate disablement.

In Aberdeenshire, MR. BARROW resumed his work in the **Aberdeenshire.** Braemar district, where he surveyed a tract of 28 square miles, with 148 miles of boundary; while in the same region $44\frac{3}{8}$ square miles were mapped by MR. CUNNINGHAM-CRAIG, including $250\frac{1}{2}$ miles of geological lines. MR. BARROW did not return to his Braemar ground after the summer, but took part in the revision of North Staffordshire, as already stated.

Further to the west, in the district of Badenoch and the **Badenoch.** Monadhliath Mountains, field-work was resumed by MR. HINXMAN, who surveyed there $41\frac{1}{4}$ square miles, with $217\frac{3}{4}$ miles of boundary. Later in the season he completed a tract of 11 square miles, with $34\frac{3}{4}$ miles of boundary, in the low grounds around Beauly, before he moved southward to take part in the revision of Dorsetshire, to which reference has already been made.

In Argyllshire six surveyors have been at work during the **Argyllshire.** past year. In the Loch Awe district MR. HILL, during his return to the district for convalescence, continued his former work, completing 15 square miles, and tracing 128 miles of boundary. Further to the north and north-west, around Ben Cruachan and in the region of Glen Etive, MR. KYNASTON has mapped $50\frac{1}{2}$ square miles with 235 miles of boundaries. In the Oban district $40\frac{1}{8}$ square miles have been mapped by MR. SYMES, with 162 miles of boundary. In the country on either side of Loch Eil, MR. GRANT-WILSON'S area of survey last year amounts to 54 square miles, and includes 201 miles of geological lines. In Jura MR. WILKINSON was able to add to his area already surveyed 52 square miles, including 274 miles of boundary-lines.

In Arran MR. GUNN surveyed 50 square miles and traced 296 **Arran.** miles of boundaries.

In Perthshire, around Strathyre and the Trossachs, MR. **Perthshire.** CUNNINGHAM-CRAIG resumed during part of the year the ground on which he had previously been at work, and completed an area of $26\frac{5}{8}$ square miles with $216\frac{1}{2}$ miles of boundary.

In the island of Skye MR. HARKER, in continuing the survey **Isle of Skye.** of the Cuillin Hills and adjoining tracts, mapped an area of $33\frac{1}{4}$ square miles and traced $647\frac{1}{2}$ miles of boundary-lines. The structure of this ground has been found to be still more complicated than that reported in the last *Summary of Progress*, for it has involved the following out of $19\frac{1}{2}$ miles of geological boundaries in each square mile of area.

The total area surveyed in Scotland during 1898 has been $610\frac{1}{6}$ square miles, and the total aggregate length of boundary-lines run has been $3,868\frac{1}{2}$ miles. Every square mile mapped has thus on the average required the tracing of rather more than six miles of geological lines.

IRELAND.—The field-work in this part of the British Isles consists in the revision of the published maps for the purpose of taking

advantage of all the fresh evidence which has appeared during the long lapse of time since many of them were issued, and of bringing them abreast of the present state of geological science. This revision has been begun with the older formations, which are being re-examined all over the east and south of the island. The Silurian tracts are now not far from completed. Last year the districts over which the work extended comprised the counties of Wicklow and Wexford, where MESSRS. EGAN and McHENRY were engaged, and of Tipperary, Limerick, Cork, Kilkenny, and Waterford, in which MR. KILROE was employed. The fossil-collector, MR. R. CLARK, generally preceded these officers on the ground, so as to supply them with palæontological data for separating the different Silurian formations, and especially for distinguishing the tracts of Lower from those of Upper Silurian rocks. A number of new fossil localities have thus been discovered. The total number of fossils collected during the year was 466.

The appointment of MR. HENRY J. SEYMOUR to fill the vacancy left by the resignation of PROFESSOR SOLLAS, has allowed the petrographical work of the service to be resumed at the Dublin office. MR. SEYMOUR has had nearly 200 fresh slides of Irish rocks prepared, and has supplied reports for the guidance of the field-work in regard to the nomenclature of the igneous rocks in the areas now undergoing revision.

Such being the general distribution of the field-work over the British Isles during the past year, some detailed account will now be given of the more important or interesting results of this work. For convenience of narrative the stratigraphical order of formations will be followed, beginning with the oldest.

PRE-CAMBRIAN.

Ross-shire.

The whole of the undisplaced pre-Cambrian rocks of the mainland having now been surveyed, the field-work of the staff was continued last year eastward, across the mountainous ground of western Inverness, Ross-shire, Sutherland, and Caithness. As already explained, the mapping of the Glenelg district has been unfortunately interrupted by the serious accident to MR. CLOUGH. To the east of that ground the work was resumed in the region of Lochs Fannich, Luichart, and Garve, by MESSRS. PEACH, HORNE and POCOCK.

MR. PEACH submits the following statement of the ground mapped by him during the year, in sheets 82, 83, 92, and 93 of the map of Scotland, embracing a tract of about 50 square miles, between Achnasheen and Garve in Ross-shire.

The schistose rocks form a continuation of those already mapped further towards the south-west, and are naturally divisible into two groups. Of these the lower and presumably the older (*a*) consists of hornblendic gneisses, which form the crests

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of folds and an overlying series (*b*) of granulitic muscovite-biotite schists and gneisses, of what is now known as "Moine" type. Loch
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(*a*) The hornblendic gneisses may be regarded as probably uplifts of the Lewisian series. They are met with in two separate areas of the district surveyed. One of these is an eastward extension of a mass of the same rock which was mapped in 1895 and was referred to in the *Geological Survey Report* for that year (p. 19). Allusion was made in that *Report* to the large size of some of the slices of the Lewisian gneiss which had been thrust forward among the Moine-schists, and this particular mass was spoken of as perhaps covering more than fifty square miles. Its dimensions, however, will prove to be vastly greater than was at that time supposed, for it has been followed for many miles further east without reaching its termination in that direction, and it evidently stretches southward far beyond the limits within which it has been mapped. The portion of the map surveyed last year forms a narrow strip which sweeps in a sickle-like form round the northern flanks of Sgurr a Mhullin (2,778 feet) south of Achanalt, and passes southwards into ground not yet examined near the head of Allt a Mhullin. Its position on the mountain is indicated by the smooth feature (so well seen from the railway) from which the fine cliffs and peaks of the Sgurr abruptly rise. The rocks which enter into its composition are chiefly granulitic hornblende-biotite-gneisses. Granulitic quartz-felspar-biotite-gneisses occur in small quantity; hornblende-schist and epidiorite much more abundantly, while ultrabasic rocks are also present which appear to have been peridotites, though now for the most part in the condition of unctuous schists with clear colourless amphibole. Epidote is a common mineral in most of the masses. The general assemblage of these rocks, together with their mode of occurrence, at once recalls the Lewisian gneiss as developed at Loch Alsh, Glenelg, Sheildaig, and many other parts of the West Coast.

The second mass lies to the south of the upper end of Loch Luichart, and shows on the map like a fork, the apex of which rests on Loch Bhàd Ghaineamhaich, about three miles south of Loch Luichart Station, while the prongs reach the shores of Loch Luichart at a distance from each other of about two miles. In addition to the types of rock already mentioned, this mass includes a white and pink crystalline marble with calc-silicates, much like the limestone of Glenelg, the outcrop of which follows the fold that makes the northern prong of the fork. As in the case of the larger mass of gneiss, the course of this less extensive slice is made evident from the railway by the smooth green pasture-covered slope to which the calcareous and decomposing granulitic hornblendic rocks give rise, and which offers so marked a contrast to the sombre vegetation and grey crags of the surrounding "Moine-schist" and muscovite-biotite-gneiss.

(*b*) The "Moine-schist" and muscovite-biotite schist or gneiss of the overlying, and therefore presumably newer, series occupy by far the greater part of the area. They may be looked on as

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the "rocks of the country." With the exception of a few foliated igneous intrusions and quartzo-felspathic veins, they consist essentially of granulitic muscovite-biotite-gneisses, varying from quartzo-micaceous flagstones or "Moine-schists," on the one side, through every intermediate grade into rocks made up of felted muscovite and biotite with included streaks, lenticles, and knots of quartz and quartzo-felspathic intergrowths of all sizes, from mere grains and films up to masses over a couple of feet across and yards in length. All these varieties are in places more or less garnetiferous, but the garnets are largest and most numerous in the more micaceous rocks and their quartzo-felspathic accompaniments. For convenience of description the more quartzose rocks will here be spoken of as "Moine-schist" or "Moine-gneiss," and the more micaceous rocks as "Muscovite-biotite-gneiss." These two types of rock have been distinguished on the map by lines and colours. The origin of the "Moine-schists" has been a problem that has constantly engaged the attention of the Survey since the rocks were first mapped in the West of Sutherland. During the last few years the conviction has been steadily gaining ground that much of these schists originally consisted of sedimentary strata. In the district surveyed last year by Mr. PEACH the schists and gneisses of the "Moine" type may be supposed to have been originally sandstones or arkoses; the muscovite-biotite-gneiss was in all probability an argillaceous rock, while the intermediate types may represent varying admixtures of these two kinds of sediment.

That these rocks were originally clastic is rendered almost certain by their colour-banding and the distinct traces of current-bedding which they still present. In this area, although the rocks have been intensely plicated, they have not been much affected by cleavage or foliation. In most cases the new micas have been developed chiefly along what appear to have been the bedding-planes. The original quartz and felspar grains have been almost entirely granulitized, and perhaps the only materials that have been left in the condition in which they were deposited are a few refractory minerals, such as rutile and zircon, with possibly the cores of some of the alkaline felspar-grains that have escaped the granulitization which has affected their outer parts. Some layers of schist appear to have been of more complex chemical composition than others, for on the west side of Loch Luichart, close to the farmhouse of Arrieleitrach, thin bands of mica-schist occur in which tourmaline is extremely abundant. Zoisite also occurs in thin beds in the Moine-schist, and as knots and lenticles in the Muscovite-biotite gneiss.

There seems to be a definite order in at least the local succession of these rocks. In that part of the district which lies east of a line drawn S.S.W. from the head of Loch Luichart, and which coincides with a line of fault to be mentioned in the sequel, Moine-schists always lie next to the older gneisses, while the centres of the synclines of these schists are occupied by the muscovite-biotite-gneiss which is here, therefore, the highest

rock of the series. A similar arrangement is met with in the part of the area to the west of the fault, but it is not quite certain that other Moine-schists may not there in turn overlie the muscovite-biotite-gneiss. In both tracts the junction between the Moine-schists and the older gneisses wherever seen is quite sharp, and while the character of the overlying rock remains constant, that of the lower series varies from one exposure to another—a relation which suggests the inference that the junction between the two rock-groups is an unconformable one. Moreover the disposition of the Moine-schist with regard to the old gneiss core on Sgurr Mhullin strongly points to an overlap of different layers of the younger rocks upon the older, and further serves to indicate that all the exposures of the older gneiss in the present area may represent the tops of ridges which still remained uncovered after a considerable part of the sediment that now forms the Moine-schist had been deposited.

Foliated Igneous Rocks—Augen-gneiss.—Several types of foliated igneous rocks occur associated with the Moine-schist and Muscovite-biotite-gneiss. On the north shore of Loch Luichart, within half-a-mile of the mouth of Corriemoillie Burn and in the adjacent railway cuttings, four outcrops appear of a fine augen-gneiss or granite, like the well-known "Inchbae" rock, of which these outcrops may possibly be the southern extension. The rock shows fine Carlsbad twin-crystals of a pink-coloured felspar (orthoclase) oriented in a definite direction and enclosed among winding wisps and streaks of a granulitic ground-mass composed of quartz, felspar, and micas, together with small crystals of garnet and sphene. The rock occurs as a sill or sills intruded more or less between the bedding planes of the Moine-schist, and shows fine-grained or "chilled" edges, where its texture is much finer and evened than in the centre, and where the porphyritic crystals seem to be absent. This fine-grained marginal material is always more or less foliated. In most places its foliation-planes have not been observed to run parallel to the cooling surfaces, but rather to cut them at a considerable angle, and to be apparently continuous with those of the adjacent Moine-schists. This augen-gneiss would thus seem to have been intruded into the original sediments before they were converted into their present condition of Moine-schists, and it may be inferred that both rocks had their present structures impressed upon them at one and the same time. There are even grounds for the belief that the four outcrops of augen-gneiss are portions of one single sill brought up to the surface by successive folds, which in that case must be isoclinal, as all the outcrops dip towards the south-east. Though such a structure cannot be demonstrated on the ground, owing to the covering of drift under which the rocks are hidden, yet on both shores of Loch Luichart, a little further south, the schists can be clearly seen in cliff-sections to have been thrown into innumerable folds of this type, wherein both limbs dip in the same direction. In fact this arrangement has constantly to be borne in mind, as it really affords the key to the structure of the whole area.

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Within a belt of ground about a mile wide, lying to the west of a line of fault which extends from the west end of Loch Luichart southwards to the bend of the River Meig at Milton of Strath Conon, dykes of fine-grained foliated granite occur. They may be studied where exposed in rock-surfaces near the bridge across the Conon south of Loch Luichart Station. As small dykes, sills, and veins, they traverse the Moine-schist in all directions. They are all granulitic and foliated parallel with the foliation of the surrounding schist, irrespective of the trend of the individual dykes.

Sills of epidiorite or massive amphibolite and hornblende-schist are found chiefly to the east of the fault already mentioned and south of a line drawn from a point about a mile and a half south of Loch Luichart Station eastward to Killin Farm, near the head of Loch Garve. They appear to have been intruded into two horizons in the newer gneiss, and to cling to them with great persistency. The lower of these horizons lies near the top of the Moine-schist, and its invading sill, now consisting of hornblende-schist, is usually larger, more continuous, and more even in thickness than that which occupies the higher horizon. The upper sill has taken its place within the muscovite-biotite-gneiss and near the base of that group. It often appears as a series of nodes or lenticles of coarse garnetiferous epidiorite or amphibolite strung together by a thin layer of garnetiferous hornblende-biotite-schist, while at other times the lenticles are quite detached from one another though still disposed in lines so as to give the impression that they are portions of a once continuous layer which has been wrenched into fragments. The manner in which the muscovite-biotite-gneiss is puckered, involved, and filled with lenticles of quartz and felspar further deepens this impression. The micaceous bands seem to have given way to pressure and torsion to a greater degree than the more rigid Moine-schist.

Structure of the Ground.—Throughout the whole area all the rocks here mentioned have been thrown into a series of folds, which for the most part are isoclinal. While the long axes of these folds vary constantly in direction, and at some part or other of the area are directed to all points of the compass, their main trend is E.N.E. and W.S.W., while the dip of each limb is usually towards the South and East. By this structure the strata have been indefinitely repeated. The order of succession of the newer gneisses having now been well established in the course of the mapping, and the hornblende-schist sills having been ascertained to occupy certain definite horizons, the great folds of the rocks have been determined, and traced upon the maps over the greater portion of the area surveyed last season.

Along the course of the fault which extends across the district southwards from the head of Loch Luichart, the outcrops of the different schists and the axes of the folds seem to have been dragged round for some distance on both sides till they almost coincide with the line of fault, as if the dislocation

had been the result of some great lateral wrench rather than that of an ordinary fault. In this case there is some ground for the belief that both lateral and vertical movements have taken place. The old gneiss core of Sgurr a Mhullin has probably been brought to the surface by the same set of folds as those of the hills south of Loch Luichart, and in that case the displacement would show the amount of lateral wrench. As possible evidence of the vertical movement, it may be mentioned that the rocks on the west side of the fault are everywhere in a higher state of crystallisation than those on the east side, and are also much more filled with igneous intrusions, which had evidently been injected prior to the faulting. This more mineralised side is therefore in all probability the side of upthrow. The course of the fault is marked by a great deal of brecciated rock, which is generally stained deep red by hæmatite, as if the schists had once been covered by a red formation which has since been wholly removed. That such a covering did really once overspread this ground is highly probable, for an outlier of Old Red Sandstone occurs just east of the line of fault on Ben Bhreac, about two miles north of Loch Luichart Lodge, just outside of the district here described.

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A few dykes of mica-trap, later in date than the production of the schistosity of the region, have been met with. One of these, about 8 feet broad, has been traced in the schists on An Cabar to the south of Loch Fannich. Another thin vein with large hexagonal plates of biotite crosses the River Bran about 3 miles east of Achnasheen, and a narrow dyke of lamprophyre occurs on the high ground between Loch Luichart and the head of Loch Garve. At Creag a Chaorinn a dyke of mica-trap may be seen to penetrate from the schist into the conglomerate, whence the conclusion may be drawn that the date of intrusion of some of these rocks must be later than at least some part of the Old Red Sandstone of the Cromarty Firth basin.

The area surveyed by MR. HORNE in this part of Ross-shire lay between Loch Fannich and the watershed of the range of the Fannich Mountains. He has been able to join up his work with that carried by MR. GUNN southwards from Loch Broom to the same watershed, which was described in the *Summary of Progress* for 1897 (p. 38). The same groups of rock traced by the latter geologist have now been followed into the area surveyed by MR. PEACH, and the general sequence of rock-groups in the region has been established. These groups, as given by MR. GUNN, are here cited in what appears to be a descending order:—

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1. Acid gneiss, granulitic and granitoid, with basic lenticles, knots and bands of hornblende-schist, epidiorite and garnet-hornblende-rock; resembling certain types of the Lewisian gneiss.

2. Massive biotite-gneiss, highly garnetiferous, with irregular masses of dark garnet-hornblende-rock. (Meall Dubh and Meall an't Sithe gneiss.)

3. Granulitic quartzose schist or gneiss; flaggy, fine-grained, light-grey, weathering white; quartz-biotite-granulite or Moine-schist. (Meall-a' Chrasgaidh rock.)

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4. Biotite-schist, dark grey to black, with small garnets in certain bands. It includes a prominent zone of granulitic grey quartzose schist. (Sgurr Mor.)

5. A thick group of massive and flaggy granulitic quartzose schists (quartz-biotite-granulites), with thin bands and partings of dark biotite-schist.

The relations of the first four of these groups are well displayed in the great corrie (Allt Choire Mhoir) which separates the two highest peaks of the Fannich chain—Sgurr Mor, 3,637 feet, and Sgurr nan Clach Geala, 3,581 feet—and likewise on the slopes of these mountains. The members of each group in succession rise to the surface, with an apparent persistent dip to the west or west-south-west. No. 1 is met with on the south-west slope of Sgurr nan Clach Geala, and No. 4 on the lofty ground round Sgurr Mor, about a mile further east. These groups of rock form more or less parallel belts, which, by means of the sections laid bare in Allt Choire Mhoir, Allt Choire Bhig, and other adjacent exposures, can be traced southwards to Loch Fannich. It is noteworthy, however, that as the respective groups are followed southwards to the mouth of Allt Choire Mhoir, west of Fannich Lodge, the westerly dips, so persistent on the watershed, give place to highly inclined dips to the east.

On the south-west slope of Sgurr nan Clach Geala the acid gneiss (No. 1), which there consists of granulitic biotite-gneiss with flaser-structure, rests on the garnetiferous biotite-gneiss (No. 2); both rocks dipping to the west at angles that vary from 20° to 35° . Southwards along the crest of the ridge from Sgurr nan Clach Geala, tongues of the garnetiferous biotite-gneiss are seen to be infolded in the acid gneiss (No. 1), and where this relationship appears the prevalent dip is no longer to the west but to the east, from 30° to 50° . Thin sills of hornblende-schist occur in the acid gneiss near its junction with the massive biotite-gneiss (No. 2). Indeed near the source of Allt Leac a' Bhealaich, that drains the south-west slope of Sgurr nan Clach Geala, bands of epidiorite and garnet-hornblende rock are associated with biotite gneisses in such a way as to recall certain types of Lewisian gneiss. Similar rocks forming part of No. 1 are met with on the hills north-east of Cabuie, in Abhuinn Nid, and on the slopes of A Chailleach (3,276 feet), the most westerly peak of the Fannich group. Thin pegmatites from one to two feet thick with small prisms of tourmaline have been detected in Allt Leac a Bhealaich north of Cabuie.

Along the crag that runs southwards from Sgurr nan Clach Geala, on the west side of Allt Choire Mhoir, the coarse garnetiferous biotite-gneiss (No. 2) forms a prominent belt from a quarter to half a mile in width. The characteristic features of this rock are, the abundance of its garnets, and the presence in it of quartzo-felspathic constituents in strings and knots. Sometimes the quartzo-felspathic materials are arranged with the biotite in parallel folia, thus forming a coarsely banded gneiss; sometimes they disappear and the rock merges into a flaky biotite-schist. In places muscovite is largely developed

and the rock becomes a garnetiferous muscovite-biotite-schist or gneiss. Fannich Forest.
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The grey flaggy quartzose schists (No. 3), well seen on the east slope of Sgurr nan Clach Geala, are inclined to the west at angles of 40° – 60° . From that point southwards they can be traced as a narrow belt about a quarter of a mile broad to Allt Choire Mhoir, where they become vertical, and eventually dip to the east and east-north-east at about 70° .

The members of the succeeding group (No. 4), consisting mainly of biotite-schists, are displayed on the col at the head of Allt Choire Mhoir, on Sgurr Mor, and on the ridge that separates Allt Choire Mhoir from Allt Choire Bhig. The prominent band of quartz-schist (quartz-biotite-granulite), about 200 feet thick, has been traced from the corrie on the east side of Sgurr Mhoir, across the watershed, to near the foot of Allt Choire Bhig. Although this mica-schist group is highly puckered, the sections on the cliffs round Sgurr Mor show that the rocks are inclined to the west, while about three miles to the south they are either vertical or highly inclined to the east or west. The bands of zoisite-rock, detected by MR. GUNN in this group, on the north side of the Fannich Mountains, have been observed at various localities between Sgurr Mor and Loch Fannich. They occur in the biotite-schist, in seams from one to three inches thick, which, on weathered surfaces, show prisms of zoisite about a quarter of an inch in length. Sometimes, where the schists are highly puckered, the zoisite rocks appear as small lenticles. Thin slides, prepared from specimens collected by MR. HORNE in this region, have been examined under the microscope by MR. TEALL, who has furnished the following description of them:—

[8,203.] West slope of Sgurr Mor Fannich. Light grey, fine-grained granulite with conspicuous prisms of zoisite about $\frac{1}{4}$ inch in length on the flat surface of the specimen. Under the microscope appear garnet (colourless in thin section), zoisite and quartz, with biotite, chlorite and sphene as accessories. Undoubtedly allied to MR. GUNN's rock, but without the hornblende; quartz-garnet-zoisite-granulite or, in short, zoisite-granulite.

[8,205. Same locality. Similar to the above but darker and containing larger garnets. Under the microscope are seen garnet, zoisite, quartz, plagioclase, hornblende and biotite. Opaque particles as in 8,204. The minerals are not uniformly distributed. The hornblende is usually in association with the felspar, and the zoisite with the quartz and garnet. The rock is more or less banded; garnet-zoisite-amphibolite.

The eastern portion of the Fannich range is composed of massive and flaggy quartzose schists with thin intercalations and partings of biotite schist (No. 5). These quartz-biotite-granulites present the normal characters of the "Moine-schists" throughout the counties of Sutherland and Ross. Along their line of junction with No. 4—the Sgurr Mor biotite-schists to the west—there is evidence of sharp plication and inversion. In the section in Allt Choire Bhig the rocks of the two groups are vertical, while on the lofty crags of the col between Sgurr Mor and Meallan Rairigidh the quartzose granulites (No. 5) have been made to overlie the biotite-schists (No. 4). The system of Z-shaped

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folding characteristic of this inversion is well seen on the cliff at the head of Allt Choire Bhig.

Along the eastern part of the Fannich range from Meallan Rairigidh by An Coileachan to the mouth of Loch Fannich the members of group 5 are arranged in a great synclinal fold, with the axis of which the crest of the range more or less coincides, in a south-east-by-south direction. On both limbs of the fold the rocks dip at gentle angles of 12° – 20° , till in the eastern limb of the chain they become vertical or highly inclined to the west. The latter area, north of the mouth of Loch Fannich, has been mapped by MR. Pocock, and will be referred to a little further on.

An interesting feature in the structure of the eastern part of the Fannich range is the occurrence of three outliers of biotite-schist, (1) on the crest of Meallan Rairigidh (3,109 ft.), (2) on An Coileachan, (3) on a hill about a half a mile to the north of the mouth of Loch Fannich. These may be outlying patches of No. 4 which have been isolated by denudation. They form thin cakes composed of flaky and granulitic biotite-schist resting on the gently inclined quartz-granulites (No. 5). The occurrence of bands rich in zoisite in the first and third of these outliers lends some support to this correlation.

No sills or bands of hornblende-schist have as yet been detected in the thick group of siliceous schists or gneiss (No. 5) in the eastern part of the Fannich range. Pegmatites are of rare occurrence. Thin veins of microcline-pegmatite have been observed in the granulitic biotite-schists of Meallan Rairigidh and a similar rock has been noted in No. 5 in Corrie Riabhach. With reference to the latter MR. TEALL states that "it is not intended to imply that soda-felspars are absent from these pegmatites, but only that microcline is present. They are not purely albite-pegmatites, such as occur in segregations in the Cowal district and in South Devon."

The survey of the western portion of the Fannich range was not completed before the beginning of the deer-stalking season, when mapping in forest ground is suspended, but sufficient evidence was obtained to prove that groups 2 and 3 appear on the western limb of the fold, to the west of A Chailleach, where the rocks of these groups dip to the east under the acid gneiss (No. 1). In other words, Nos. 2 and 3 can be traced continuously from the west slope of A Chailleach, where they have an easterly dip, round the northern limit of the syncline, thence to Sgurr nan Clach Geala, where, as already indicated, they rise to the surface with a westerly dip.

Two hypotheses may be advanced to explain these geological relationships, where the acid gneiss with basic masses seems to rest on the underlying groups 2 and 3. (1) The structure may be analogous to that north of Loch Maree, where the biotite-gneisses and hornblende-schists of Meall Riabhach are superimposed on the sedimentary series of Letterewe, or (2) the structure may be fan-shaped, the rocks of Lewisian facies (No. 1), though apparently the highest, may in reality be the lowest, while the sequence of

the other groups may be deceptive. Of these hypotheses, the first seems the more probable. Indeed, the uniform characters of the Moine-schists, Nos. 3 and 5, and their persistence without modification throughout the folded area of Fannich, suggest the probability that their crystalline characters were developed prior to the Post-Cambrian movements.

The ground surveyed by MR. POCOCK in the same tract of Ross-shire lies partly to the east and partly to the west of the ground that has been mapped by MR. HORNE, and includes the same groups of rock. The eastern part of his area comprises a portion of the rough ground north and south of the lower end of Loch Fannich. Here the rocks have been found by him to be remarkably uniform in character and structure. They consist of flaggy quartzose gneisses alternating with dark-coloured biotite-schists, in vertical beds, having a general north and south strike. On the whole, the quartzose gneiss is predominant, but a well-marked zone of biotite-schist, with but few bands of quartzose schist, has been traced for a distance of about four miles across the area. On the western side of this micaceous zone the breadth of the vertical series of quartzose schists is a mile and a half. Beyond this, on the west side, the beds arch over abruptly, and rise into the great cliffs of Ben Aigean, which form so striking a feature as seen from the road to Fannich Lodge. On this cliff the strata dip somewhat steeply to the S.W., but they flatten considerably as they are traced round the escarpment on the north side of the Fannich Hills into the ground mapped by MR. HORNE, where their inclination falls to no more than 20°. At the top of the Ben Aigean cliff overlying the quartzose schists a slight synclinal fold holds an outlier of the Sgurr Mor biotite-schist (No. 4 of the Table on p. 12). The quartzose schists here as elsewhere belong to the typical "Moine schists" (group No. 5). The biotite-schist zone, just referred to as occurring to the east, is closely similar in character to the Sgurr Mor schist, and most probably is a mass of the same rock folded into the quartzose series to a depth of about 1,400 feet on a north and south axis. It is intensely puckered, and is full of twisted lenticles of vein-quartz. It is well seen on the top of Càrn na Bèiste, a mile east from the lower end of Loch Fannich, where it attains a maximum breadth of half a mile. The crag at the summit of that hill is formed by a prominent quartzose sub-zone, which stands up above the softer features of biotite-schist on either side. The same biotite-schist forms the summit of Ben Dearg on the north side of the Grudie River, and is also seen 1,400 feet below the top of the hill in the river section, but is there much split up by quartzose bands. The smaller breadth of the zone at this lower level may indicate that the bottom of the fold is not far below that point. Traced southwards into the ground surveyed by MR. PEACH, the biotite-schist rapidly splits up and dies out.

The quartzose gneiss on the east side of the biotite-schist zone resembles the Ben Aigean series in general characters, but is somewhat more massive, and in places contains thin folia of pink felspar. It rises into the prominent crag which forms the

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eastern shoulder of Càrn na Bèiste. The zoisite-amphibolite-rock already referred to, as described by MR. GUNN from the biotite-schist, has been found abundantly in the quartzose-schist on two horizons on the Ben Aigean cliff, and also on the low ground to the east near the mouth of Allt a' Choin Idhir.

The western part of the area mapped by MR. Pocock includes some ground to the south-west of Loch Fannich, in which Beinn nan Ramh (2,333 feet) is the most conspicuous mountain. On the western slopes of this high ridge he has found a group of granulitic quartzose mica-schists which, dipping to the east at about 20° , are finer-grained and more flaggy than the typical Moine-schists of the district to the east just described. There can be little doubt, however, that they represent some part of the Fannich and Luichart series. When the ground lying to the north has been surveyed in detail, MR. GUNN's zones will probably be identified here also. So far as the mapping has yet gone, the biotite-schists appear to be here thinner and more split up by quartzose bands. From the river section, one mile east from Leckie, a belt of biotite-schist, about 600 feet thick, extends over the peaty plateau to the north. It is evenly foliated without much puckering, and may represent one of the micaceous zones which attain a greater development in the Fannich region owing to the extent to which their folia have been plicated. Above the biotite-schist in apparently ascending order, an alternating series of micaceous and siliceous schists passes up into massive granulitic quartzose gneiss. One or more ill-defined belts of biotite-schist occur in this series, the total thickness of which may be nearly 4,000 feet, measured from the top of the belt of biotite-schist near Leckie. The zoisite-amphibolite-rock is found occasionally here also in bands one or two inches thick.

The summit and eastern slopes of Ben Ramh are occupied by a complex group of gneisses of different character, which apparently overlie the Moine-schists just described. They are distinguished by the frequent presence of dark hornblendic patches and dykes. The most prominent member of the group, occupying by far the largest part of Ben Ramh, is a coarse flaky garnetiferous gneiss first found by MR. HORNE on Meall Dubh. In its most typical form it consists of coarse muscovite and biotite folia, is full of dark red garnets, and contains lenticles of pegmatite from a quarter of an inch to an inch in thickness. But it presents considerable variations of character. Some of its finer-grained portions contain little or no pegmatite and cannot be distinguished in hand specimens from the ordinary micaceous Moine-schists. Others display the pegmatite drawn out into parallel folia and in such large proportion that the rock assumes an acid character, while a third class presents muscovite developed almost to the exclusion of biotite. The pegmatites of this rock deserve special mention, as a few of the larger veins, which are several feet thick, contain a beautiful rock made up of large muscovite plates varying up to three inches in diameter set in a quartzose matrix which is crowded with small stumpy prisms of black tourmaline; a few of the tourmaline crystals attain a

length of four or five inches. The hornblendic portions of the flaky gneiss, though sometimes traceable as dykes for short distances, usually take the form of irregular rounded masses of eclogite. A boulder from one of them, found on the east side of Ben Ramh, contains a vein with crystals of black hornblende three quarters of an inch long. Loch Fannich and Loch Luichart. (Mr. Pocock.)

Closely associated with the flaky gneiss is a granitoid gneiss made up of coarse white quartzo-felspathic layers with intensely contorted micaceous folia. It is well seen on the eastern slopes of Ben Ramh, where it is folded up with the flaky gneiss on a general N.W. and S.E. axis. Further west several distinct outcrops of a similar rock occur, some of which pass into a fine-grained quartzose gneiss with thin folia and "eyes" of felspar similar to MR. GUNN'S "Acid gneiss" (No. 1). The basic portions of the granitoid gneiss usually appear as hornblende-schist dykes, traceable for short distances, and folded with the main mass of the rock. East and west of the main outcrop of flaky gneiss, but folded with it, are masses of quartzose gneiss belonging probably to the Moine-schist series, but placed in this group on account of the presence of hornblende-schist dykes. In many parts the rock is indistinguishable from the typical quartzose Moine-schist, whilst in others the occurrence of thin felspathic folia and "eyes" associates it with the Acid gneiss.

Only one example of later intrusive igneous rocks was observed. This is a small lamprophyre sill which occurs near the southern shore of Loch Fannich.

At the close of the work for the season among the Fannich mountains MR. HORNE moved into Easter Ross and continued his mapping of that district. The ground there examined by him included some small tracts of schistose rocks. In the neighbourhood of Rosemarkie these rocks rise up from under the Old Red Sandstone as the crystalline axis long ago described by Hugh Miller. The best section in the area mapped last year is to be seen on the shore, but the original characters of the rocks have there been greatly altered by the action of the great dislocation which extends from Loch Ness and the Great Glen up the eastern coast-line of Ross-shire. The rocks have been so brecciated that they break up into small angular fragments, and a fresh fracture is consequently difficult to obtain. They consist of flaggy granulitic biotite-gneisses with thin bands and lenticles of hornblende-schist and actinolite, traversed by numerous veins and irregular masses of a pink granitoid rock. The latter type of igneous material is well seen on the side of the road in Rosemarkie Glen. Easter Ross. (Mr. Horne.)

Another small area of crystalline schists was mapped by MR. HORNE on the west bank of the Beaully river along the western margin of the Old Red Sandstone. The rocks consist there of grey granulitic quartz-schists (quartz-biotite-granulites) with thin bands and partings of biotite-schist, the latter sometimes containing muscovite. Thin veins of lamprophyre occur in these schists near Aigas. Near the margin of the Old Red Sandstone, east of Glen Convinth, the schists consist of biotite-gneisses, Inverness-shire—Kiltarlity district. (Mr. Horne.)

with thin highly-contorted folia of granitic material. This series is traversed by veins of granite and pegmatite which recall the type of composite gneisses in the east of Sutherland.

A small area of metamorphic rock to the north-west of Beaully, also mapped last year by MR. HINXMAN, is occupied by a series practically identical in lithological composition with the rocks of Upper Strathspey. These rock-types are also practically identical with those examined by MR. B. N. PEACH in the Loch Luichart district above referred to, as well as with those traced by MR. GRANT-WILSON far to the south at the head of Loch Eil on the West Coast. Rocks of similar lithological types have thus been identified in widely separated areas on both sides of the Great Glen; and it seems probable that these two groups will be found persistent throughout much of the unsurveyed parts of the Highlands.

Caithness.

(Mr. Pocock.)

On the conclusion of the brief season during which mapping is possible in the Fannich Forest MR. POCOCK resumed his field-work of the previous year in Caithness, and mapped an additional area of the schists which in that county rise from under the wide undulating plain of Old Red Sandstone between Glut Lodge, the south side of the Morven range, and Braemore.

The rocks in this tract of ground were found to consist of (1) fine-grained granulitic quartzose gneisses and mica-schists, with granitoid folia and thin bands of granite; (2) coarse-grained rudely-foliated orthoclase-gneiss, with large crystals of pink orthoclase; (3) massive snow-white quartz-schist. The first of these groups is the same as that described in the *Summary of Progress* for 1897 as occurring near the granite mass in the Glut Water. A narrow belt of the same rocks is found in the Berriedale Water near Corrichoich, where their relations to the granite are similar. Occasionally the ordinary type of Moine-schist is met with, but most commonly the gneiss contains thin granitoid folia made up chiefly of quartz and felspar. In no case, however, have chilled margins been observed either in the folia or in the larger veins of granite. So thin are some of the granitoid folia that in hand-specimens the composite nature of the rock cannot be recognised. A striking resemblance to the "acid gneiss" of Loch Fannich is thus induced in the more quartzose portions of the schists, while the mica-schists, which become coarse and contain lenticles of pegmatite, approach in lithological character the flaky gneiss of Meall Dubh. The occurrence of coarse intrusive pegmatites may here be noticed. They are found in masses several feet thick, and consist of plates of muscovite two or three inches in diameter, with white felspar crystals set in a matrix of quartz.

The orthoclase-gneiss is found extensively on the low ground on the north side of Morven. It forms a belt which crosses the Berriedale Water at some distance to the west of Corrichoich and thins out eastwards between two masses of granite.

A small inlier of the same rock occurs within the Old Red (Mr. Pocock.) Sandstone area, half a mile west of Braemore Lodge. The characteristic feature of the material is the presence in it of large crystals of orthoclase, varying up to two inches in length. The crystals are perfectly formed or show a graphic intergrowth of quartz, and are surrounded by folia of dark greenish mica. Augen-structure is frequently found, but in places the orthoclase-crystals are so thickly crowded that the foliation of the rock is almost obliterated. Though so different in lithological characters from the composite gneisses above referred to, it belongs to the same series and has a similar origin. This can be seen in one of the burn-sections at the foot of Morven. A mica-schist is there exposed of the Moine type with folia of coarse pink pegmatite, and thin dykes of the same material with large pink orthoclase cutting across the foliation. A similar rock has been described by the Director-General in his Memoir on the Old Red Sandstone* as occurring on the north side of the Scaraben Range. The quartz-schist appears in four separate masses in this area, the largest of which is the Small Mount on the west side of Morven. It is of uniform character throughout and quite distinct from the quartzose Moine-schist. It is composed almost entirely of quartz in folia a few inches thick, much folded and dipping at steep angles in the same direction as the Moine-schists. Sometimes a little white mica is found between the folia, with vein-quartz cutting across them. The quartzite is seen in contact with the Moine-schist on the north-side of the Small Mount, but in other places the junction is obscured by the unconformable overlap of the Old Red Sandstone. Each of the four masses occupies high ground, and the quartzite cannot be traced across the intervening low ground. They occur as outliers resting upon the Moine-schists, though they appear to be folded up with and conformable to the lower series. No instance of granite veins intruded into the quartzite has been observed.

The granite mass, described in the *Summary of Progress* for 1897, from the hills west of Glut Lodge has now been traced southwards into the Berriedale valley. The lines of structure change somewhat abruptly about three miles south of Glut Lodge, from a north and south to an east and west direction. The granite is exposed in the upper reaches of the Berriedale water near Goberniesgeach, and passes in an easterly or north-easterly direction along the left bank of the river nearly as far as Braemore, whence it crosses the watershed into the Dunbeath valley and passes under the Old Red Sandstone. It presents the usual features, which have been described in former Reports. In this district, however, it is rarely foliated. Along its margin it is often coarse and highly micaceous, and it is cut by veins of more acid pink granite. The pink granite, which is a later intrusion, and is distinguished by the colour of its felspar from the grey rock just referred to, attains a considerable development on the north side of the Dunbeath Water, where it has

* *Trans. Roy. Soc. Edin.*, vol. xxviii. (1878), p. 369.

(Mr. Pocock.) furnished the materials of which the basement beds of the Old Red Sandstone are composed. It is to this later intrusion that the pink pegmatites of the orthoclase-gneiss described above are attributed. An earlier basic intrusion was observed a short distance east of Guberniesgeach. It is a quartz-diorite, containing a little brown mica, and it appears to be of considerable extent, but has not yet been completely mapped. It is cut by veins of white pegmatite.

DALRADIAN OR YOUNGER SCHISTS OF THE SCOTTISH HIGHLANDS.

In continuation of the arrangement followed for some years past in the distribution of the field-work in the Highland region to the east of the Great Glen, a series of stations has been taken by the Surveyors, from Aberdeenshire in the north-east to Argyllshire in the south-west. In the upper part of the Valley of the Dee MR. BARROW and MR. CUNNINGHAM-CRAIG have prosecuted the survey of the high grounds to the north and south of the valley. MR. HINXMAN has carried his mapping further into the upper basin of the Spey and the Monadhliath Mountains. Further to the south MR. CUNNINGHAM-CRAIG was occupied during part of the season in surveying certain tracts that remained to be completed in Perthshire. Towards the south-west, some parts of the crystalline schists came into the area surveyed by MR. KYNASTON around Glen Etive and Loch Awe. In the Oban district additional tracts of these schists have been mapped by MR. SYMES. On both sides of Loch Linnhe and Loch Eil fresh ground was broken by MR. GRANT-WILSON. Among the islands a considerable new tract in Jura was mapped by MR. WILKINSON, and in the northern half of Arran the survey of the belt of schists was continued by MR. GUNN. Each of these officers has furnished an account of the progress of his work, and their reports are here inserted in the geographical order just given.

Aberdeenshire.

Braemar.
(Mr. Barrow.) In the district of Braemar surveyed by MR. BARROW the same highly quartzose rocks described in previous Reports have been encountered, and have been found to be still disposed in isoclinal folds. In the great mountains of quartzite, which form so conspicuous a feature in the scenery of the Central Highlands, the limbs of these folds can be seen to be for the most part straight, and to be inclined at a high angle. This structure is displayed among the Ben y Ghlo Mountains up to a height of 2,400 feet. Further to the north, however, in the direction of Braemar, these straight limbs begin to "buckle," and this "buckling" continues till a series of approximately horizontal

minor plications is superinduced on the older vertical or straight-limbed folding, as may be clearly seen in the quartzite mountain south-east of Braemar. The structure thus produced is identical with that observed in the Moine-schists or eastern gneisses of Sutherland, Ross, and Western Inverness-shire. It is found over the whole of the district to the north of the Dee, though owing to the great number of normal faults, the horizontality of the bedding planes has been considerably disturbed. An examination of scar-faces, such as those seen in the Sluggan Burn, indicates that, in spite of the horizontality of the bedding, some distinctly recognisable band may be found to ascend vertically through the mass of rock. At the top of the main quartzite a peculiarly fine white siliceous band of a very distinctive character forms a readily traceable horizon, by means of which the total original thickness of the pink and grey quartzose rocks above the quartzite proper can be proved to be really small—probably not more than 30 feet. This white band is met with repeatedly in every direction, and its constant repetition indicates that in spite of the great area which they cover, and the apparently great thickness which they reach, these quartzites must be reduplicated again and again upon each other. As in the area south of the Dee, the highly quartzose rock above the true quartzite is often replaced by the black schist, or rather, in this part of the district, by hornfels, with its associated tremolite-rock. The hornfels rocks, or dark schist, as well as the pink and grey quartzose rocks, both rest on the top of the white quartzite, and one occurs to the exclusion of the other. The little band of tremolite rock, originally an impure limestone, has proved of great importance as a stratigraphical horizon. By means of it the quartzose rocks above which it occurs can be proved to be a continuation of the Central Highland Quartzite, in spite of the difference in aspect which the “Moine”-structure imparts to the rocks as a whole. Thus the tremolite-rock, taken together with the white band at the top of the quartzite, affords evidence that the original thickness of this part of the Highland series was small. After walking for hours across the line of strike, with the dip persistently in one direction, the observer may end at exactly the same horizon as that from which he started.

Attention has been drawn in previous Reports to the occurrence in the Highlands of rocks that present a brittle cross-fracture, are entirely devoid of true schistosity, and display a structure and composition identical with those found in rocks that have been invaded by or engulfed in granite masses. In the course of the field-work last year this type of alteration has been observed to be largely developed in what was originally a dark shale that accompanied the limestone. The metamorphism along what may be conveniently called the central part of the zone of alteration has resulted in the production of a dark cordierite-hornfels with a resinous cross-fracture; a rock of this type extends in a series of disconnected masses probably as far north as the area formerly surveyed by MR. HINXMAN, about Loch Builg.

Braemar.
(Mr. Barrow.)

As the cause of this type of alteration is a matter of dispute, a summary may here be given of the facts observed regarding it in the Braemar district. While rocks that were originally grey shales or calcareous shales frequently show this type of alteration, those that were originally sandy shales seem rarely to show it, but are almost always more or less schistose, or in highly crystalline areas, gneissose. Some connection may therefore be presumed to exist between difference in mode of alteration and difference in composition. So far as MR. BARROW'S experience has gone, the "hornfels" type of alteration has been found by him only in those areas of the Highlands where the portion of the older granites occurs that was intruded prior to the schistosity-movements, such as the well-known Ben Vuroch granite. The indurated aspect of this type no doubt often extends considerably beyond the area where the igneous material appears at the surface, but the careful examination of a large area has served to point out a close connection between the early intrusions and the hornfels type of alteration.

In illustration of these conclusions reference may here be made to the Braemar district, in which a train of intrusions of the early intrusive material has been traced along a line that extends for some 30 miles from the lower end of Glen Tilt to some distance beyond the valley of the Dee. This line is as straight as an arrow, and in every instance the more distinctly contact (thermometamorphic) type of alteration is met with around these intrusions. The effect of the uprise of the plutonic material on the rocks penetrated by it has naturally depended upon the amount of igneous material present, and in the Braemar area where these intrusions are small in amount MR. BARROW infers that the granite, being injected before the development of the schistosity of the rocks, simply indurated the grey and calcareous shales, but did not indurate sandy shales. Hence the indurated shales were afterwards able to resist the schistosity-movements, while the non-indurated shales did not possess cohesion enough to do so. Owing to the enormous force of these movements the margins of an area of early induration are always broken down, the hornfels-rock being cut up into lenticles. This lenticular dislocation is an extremely common feature of areas in which the hornfels-type of alteration occurs. From a comparison of the broken down part with the unmoved hornfels-rocks it is inferred that the crystallisation which they display has mainly taken place since the breaking down or schistosity-movements, for both kinds of rock are practically equally crystalline. A small patch of the early induration has escaped crushing quite close to the margin of the newer granite of the great Cairngorm tract. Comparing this patch with the hornfels-rock nearer the Bridge of Dee area, MR. BARROW has noticed that the contact-type of alteration (felspar-hornfels) is less pronounced close to the great mass of granite than it is at a distance of three miles off. Again he has observed that in Glen Cluny there is still clearer evidence that the Lochnagar granite, which is also one of the younger intru-

sions, has not produced the hornfels type of alteration. Where the older granite comes to the surface at Newbigging, about four miles south of Braemar, the indurated or hornfels aspect of the altered grey shale (now andalusite hornfels) is well marked.

In continuing his work northwards from the line of the river Braemar.
Dee in the Braemar district, MR. CUNNINGHAM-CRAIG observed (Mr. Cunningham-Craig.)
some marked differences in the characters of the crystalline schists from those previously described. He found the change to take place somewhat suddenly along a line which, in the neighbourhood of Braemar, coincides practically with the course of the Dee.

As far as can be observed, this change in the character of the rocks cannot be accounted for by either a fault or an unconformability, but appears rather to be due to a comparatively sudden alteration in the character of the metamorphism. To the northward of this line the rocks appear to have suffered to a much greater extent from shearing, prior to granulitization. In consequence, the normal rock-type of this area is a banded and flaggy granulitic gneiss, the different bands being frequently sharply defined, and varying considerably in composition. Dips are almost invariably low and undulating.

Except for one small exposure immediately north of the alluvial flat at Braemar, the limestone and black schist, already described in former Reports, do not appear in this area, till brought up by the Clais na Fhearna fault in Glen Lui, six miles to the westward of Braemar. The prevailing type of rock is a granulitic biotite-gneiss, essentially siliceous, but frequently containing very felspathic bands. Muscovite is sometimes conspicuous, and is often developed in felted plates on the foliation planes, giving the rock a schistose character. Biotite is invariably present, the quantity varying in different bands. What is known as "colour-banding" (*Summary of Progress* for 1897, p. 48), the presence of thin laminæ of heavy minerals, concentrated and deposited by current action, may occasionally be detected.

Certain horizons are marked by thin bands of quartzite closely resembling in texture the saccharoid quartzite of the area south of the Dee, but a parallel structure is more prevalent, muscovite having been developed on the foliation planes at the expense of the felspar.

The relations of this series of flaggy granulitic biotite-gneisses between the Dee and the Cairngorm granite (described in last *Summary of Progress*, pp. 47-52) to the limestone and black schist, are not clearly seen in the eastern part of the area surveyed by MR. CUNNINGHAM-CRAIG, the section near Braemar, where calcareous and argillaceous rocks are exposed, being much complicated and obscured by igneous intrusions. The lower part of the section, however, displays an impure sheared quartzite, which appears to be in conformable succession with the calcareous rocks.

Sections in Glen Lui and Glen Derry, six miles west of Braemar, show that in traversing this series of gneisses we are never far from the horizon of the limestone. A fault, running

Braemar.
(Mr. Cuning-
ham-Craig.)

approximately north-east and south-west, brings up the limestone with an included fold of black schist, and the calcareous rocks are folded with the gneiss in precisely the same manner as the quartzite and limestone are folded in the Glen Ey area, the only difference being that the folds in the northern tract are approximately horizontal. At one point a thin band of quartzite is noticed between the margin of the limestone and the gneisses.

The series of granulitic flags and schists thus appears to take the place of the quartzite, and as no evidence has been found of an unconformability between the isolated quartzite bands and the flaggy gneisses, the two types of rock would seem to be equivalents. A section south of the Linn of Dee, approximately on the line where the effects of shearing become more conspicuous, confirms this inference by exposing several bands of saccharoid quartzite, folded and apparently intercalated with massive bands of biotite-gneiss, which do not exhibit a banded or flaggy aspect. In the area for some distance to the southward, similar intercalations are to be seen, the quartzite gradually becoming more predominant. Northward, on the other hand, the quartzite becomes less conspicuous, and the rocks lose their massive character under the influence of shearing forces, so that they appear as flaggy and banded gneisses and schists. The evidence hitherto obtained points therefore to the conclusion that these granulitic and flaggy gneisses are the representatives of the quartzite, which seems to have undergone some change in its original lithological character as it stretched towards the north, whilst it has also partly, no doubt in consequence of its change in composition, suffered to a greater extent from the effects of the shearing forces.

The cause of the greater shearing in the northern parts of the district may probably be looked for in the bending over and flattening of the isoclinal folds, along a line to the south of and parallel to that which marks the southern limit of the shear area. Such a bending of a vertically packed isocline must necessarily have been accompanied by shearing stress in the horizontal limb.

In Glen Lui, immediately above the limestone escarpment, about thirty feet of a band of peculiar granulites are exposed between the limestone and the granulitic gneiss. These rocks are finely-banded, rich in alkali-felspar, and destitute of quartz, while their other constituents give evidence of such an alkaline composition as to suggest an originally igneous origin for their material. MR. TEALL, who examined several specimens, has determined aggrine in one band, and this mineral has since been detected in other bands. Biotite and a pale garnet are always present, while muscovite and epidote characterise certain bands. Near the limestone a band of actinolite-schist, possibly representing the impure edge of the limestone, has been recognised, while a pale tremolite-schist may also be seen among the felspathic granulitic bands. It is hoped that subsequent examination and research may determine the origin of these granulites. Meanwhile it is clear that the felspathic bands have become

incorporated with material at the margin of the limestone during the movements and metamorphic processes which preceded granulitisation. The following determinations were supplied by MR. TEALL from his examination of some of the specimens:—

Braemar.
(Mr. Cunningham-Craig.)

"[8216.] Epidote-granulite. A somewhat coarse-grained granulitic or granular aggregate of alkali-felspar, epidote and green biotite, with a colourless garnet, sphene and apatite as accessories. The apatite occurs in hexagonal prisms and has all the characters of the apatite of igneous rocks."

"[8217.] Ægirine-granulite. Alkali-felspar, yellow garnet, ægirine and biotite, with magnetite in sharply defined octahedra, apatite and probably sphene as accessories. The garnet occurs in more or less idiomorphic crystals and as aggregates. It resembles in colour the pale tints of the melanite of the borolanites. The ægirine is bright green; it can be definitely determined by examining the powder of the rock. The prismatic fragments give nearly straight extinction, and the greatest axis of elasticity is approximately parallel to the long axis of the fragment."

"[8273.] Mica-schist. Alkali-felspar similar to that in the above rocks, white mica, chlorite and colourless garnet largely replaced by chlorite; with epidote, sphene and apatite as accessories.

"The distinguishing feature of the group is the presence of an alkali-felspar containing both potash and soda, and therefore probably belonging to the anorthoclase group. This taken in connection with the absence of quartz distinguishes the group from all the other Highland schists. The presence of ægirine and of a garnet allied to the garnet of the borolanites is another peculiar feature."

The younger Granites of the Grampian Hills.

While working in the Braemar district last year MR. BARROW (Mr. Barrow.) and MR. CUNNINGHAM-CRAIG have been able to add to our knowledge of the characters of the younger masses of granite which occupy such extensive tracts of the central Grampians. Each of these observers has furnished the account of his own observations.

In the area examined by MR. BARROW he has observed four rock-types among the younger granitic intrusions: 1, Diorite; 2, the great masses of red granite (Cairngorm, Lochnagar); 3, residual white or pale granite with biotite; 4, residual white or pale granite with muscovite and a little biotite.

The Diorite varies much in composition, and appears repeatedly over an area bounded to the north by the Cairngorm granite mass, to the south by the Dee, and to the west by a line drawn from Invercauld House due north to the head of the Gairn. In the western part of this tract the intrusions of the rock are extremely numerous. They vary in size from patches only a few yards broad to masses 100 yards broad and a quarter of a mile long. Further east, while small patches are still fairly frequent, the larger attain greater dimensions till they eventually merge into one of the great masses of diorite which occur at intervals on the north side of the Dee from Braemar to the coast. The abundant small patches may be regarded as simply projections from the upper surface of a large mass which must extend for a considerable distance over this district at no great depth below the present surface.

(Mr. Barrow.) The acid residual material (3 and 4) is of special interest. It occurs as a great number of small intrusions, which are usually coarsely crystalline in texture up to their margins. These small intrusions of the biotite-bearing granite are so common on Cairn Liath as to closely simulate the phenomena of permeation, so often shown by the older granites; the chief difference being that they are clearly intrusions, and do not present the appearance of being part and parcel of the altered rocks, as the older granite so frequently does. In many cases they seem to have fused the edges of the diorite, when in actual contact with it, and then the pale granite contains numerous wedge-shaped sphenes, obviously derived from the diorite in which the sphenes are abundant. Moreover, the granite in such cases is well foliated. The tendency to foliation is not, however, confined to the rock at the edges of the diorite, it occurs over the whole southern part of this area, being specially well shown to the east of Braemar.

From its whiteness, hardness, frequent foliation, and the presence in it of minerals hitherto only met with in the older granite, this granite was classed with the latter rock in the *Summary of Progress* for 1897. This view of its relations has now been abandoned by MR. BARROW, for he has since found that, notwithstanding its resemblance to the older granite, it actually intrudes into and must therefore be younger than the diorite, which can be proved to be much later than the older granite. Along its junction with the diorite this granite, which assumes so deceptive a likeness to the material of the earliest intrusions, passes insensibly into the more basic rock, and includes a considerable number of the wedge-shaped sphenes, so characteristic of the latter in this area. A good instance of this passage is met with on the foot-path from Invercauld to Loch Builg at the north end of the Invercauld woods; and similar passages may be seen further north. The hard white sills of the Braemar area, into which this pale granite passes, were also supposed to belong to the earlier granites; but there can now be no doubt that both should be considered members of the newer granite series.

With regard to the origin of this pale granitic material, MR. BARROW is disposed to look upon it as a residual acid part of the younger granite, which was the last to separate out. Like the residual parts of the older granites, it shows pegmatite or graphitic structures in a great number of instances. It again resembles the pegmatitic material of the older granites in the local abundance in it of garnets and epidote, though these minerals are entirely absent from a considerable number of the small intrusions. So far as at present known the garnets occur in no other part of the newer granite, nor has this pale acid material been observed to exist in considerable quantity in any other part of the Highlands.

The acid material containing white mica often makes its appearance inside the great Lochnagar mass of granite, but is never coarsely crystalline. Its junction with the main body of

granite is always sharp in a hand-specimen, and its margins are (Mr. Barrow.) fairly fine-grained. The tendency to minute subdivision, so marked in the area invaded by the diorite, is entirely absent in the granite.

The Cairngorm Granite.—A large part of this extensive intrusion has now been mapped. Its northern and western tracts have been examined by MR. HINXMAN, as stated in former Annual Reports. MR. BARROW has touched it on its eastern border, while MR. CUNNINGHAM-CRAIG has last year entered upon its southern heights.

The small part of the Cairngorm granite mapped last year by MR. BARROW is situated about the head of the valley of the Gairn. The rock is there of the usual red colour, and is composed of potash-felspar, quartz, plagioclase, and a little brown mica. It contains more potash-felspar and less brown mica than either the Lochnagar or the Kincardineshire masses, and it is on the whole slightly more acid. Like those masses it is always much decomposed near the surface, so that a good specimen for microscopic examination is not readily procurable. Although the actual junction of the igneous rock with the adjacent altered sediments is not to be seen, a narrow gully has been eroded along the boundary line for more than half a mile, exposing the bare granite and the altered sediments within a few feet of each other on opposite sides. The granite is apparently somewhat coarse in grain up to its margin, but along its borders there occurs a great number of more recently intruded patches of the peculiar soft red granite, full of cavities, that is so abundant on the margin of the granite near Ballater. This substance varies in texture from a markedly coarse rock to a comparatively fine one, but no evidence has been obtained to account for the curious variation in texture. The adjacent altered sediments are singularly free from igneous material. No trace of any permeation of these rocks by material proceeding from the great granite mass has been detected here. A specimen taken six feet from the edge of the granite has been found to be identical in crystallisation with a specimen of similar composition taken two miles distant from the granite. In this district therefore the granite does not appear to have produced any appreciable metamorphism of the adjacent rocks.

In the area of the upper basin of the Dee, mapped last year (Mr. Cunningham-Craig.) by MR. CUNNINGHAM-CRAIG, other masses of the younger granite intrusions were examined. In the very heart of the Cairngorm Mountains, near the head of Glen Derry, he came upon an irregular mass of basic diorite, covering nearly a square mile of ground. On its northern and southern sides this mass is bounded by granulitic biotite-gneisses and granulites, while on the eastern and at one point on the western side it is in contact with the Cairngorm granite, which also surrounds and includes the granulitic gneisses. The intrusion of this diorite has taken place prior to that of the granite, and where the two rocks come together a good example of "mélange"-junction is seen; the granite

(Mr. Cunningham-Craig.)

has apparently fused the margin of the diorite, and considerably modified the composition of the affected zone by the introduction of acid material. Thus, in passing across the junction from granite to diorite, the granite is observed to become finer in grain, and to contain more biotite, this is succeeded by a rock which MR. TEALL has examined microscopically and describes as "biotite diorite composed of zoned and more or less idiomorphic plagioclase (oligoclase-andesine), biotite, interstitial quartz and iron ores," while, farther on and throughout the main mass of the diorite, the rock has been found by the same observer to be composed of "labradorite, biotite, augite, fibrous hornblende, in large part, if not entirely after augite, and iron ores," and may be described as an "augite diorite."

In the thirteen square miles of Cairngorm granite that were surveyed last year by MR. CUNNINGHAM-CRAIG, three types have been recognised and separated by him. They appear to be of slightly different ages, but their relations to one another are not as a rule clearly shown. Their junctions with each other are usually marked by a sharp and distinct line which frequently shows itself at the surface in a hollow feature. In one case at least it can be proved that one of the types is intrusive in the main granite mass.

The chief body of the rock is a coarse red granite, consisting of orthoclase, oligoclase, quartz and biotite; the orthoclase frequently occurs in large, almost porphyritic crystals, showing Carlsbad twinning, while the scarcity of biotite, and the distinct development of the quartz are almost invariable characteristics. Near the margin of the mass, the texture of the granite becomes finer, and the quartz occurs in rounded blebs, with a tendency to idiomorphism, while in the heart of the mass the quartz is gathered into dark aggregates which appear very prominent, owing to the clear nature of the mineral. It is as a lining to drusy cavities in micro-granite veins in this coarse granite that the "cairngorm" crystals are found.

The second type is a very fine granite or micro-granite, consisting of oligoclase, orthoclase, quartz, biotite, and muscovite. The muscovite is not present in such quantity as the biotite, and the orthoclase is often moulded upon, and includes more or less rounded grains or crystals of quartz. The rock not infrequently contains porphyritic crystals of quartz, and others of orthoclase showing Carlsbad twinning. This type of granite forms the summit of Beinn a' Bhuidh, and is exposed chiefly on the high ground, as in Coire Ruaridh and Beinn Bhreac. At the latter locality it is distinctly intrusive in the coarse granite, and hand-specimens showing the junction may be obtained. It is worthy of note that this fine granite closely resembles the veins and dykes with drusy cavities in which the "cairngorms" were formed.

The third type of granite is a pale pink or occasionally white medium-grained biotite-granite. No large crystals of orthoclase have been observed in this rock, while the biotite is more abundant than in the other two types, and occurs in rounded

plates. In many respects this variety resembles the Auchindryne granite; and from its mode of occurrence the rock, which has only been observed on Beinn Bhreac, appears to be intrusive in the main or coarse granite; but its relations to the microgranite are not clearly seen, though the two rocks are in contact near the eastern summit of Beinn Bhreac. (Mr. Cunningham-Craig.)

Some interesting evidence has been obtained concerning the form of the Cairngorm granite intrusion. The actual margin of the granite in the ground examined is only to be observed at one place (Lochan a' Bhata), where a tongue of granite with approximately vertical sides is exposed at a height of nearly 2,000 feet on the ridge between Glen Derry and Glen Dubh. Numerous veins and small irregular sill-like intrusions are there to be noticed in the metamorphic rock; but this tongue may perhaps be more correctly considered as an offshoot from the main intrusion, and not important as giving evidence of the form of the intrusion. The granite boundary, however, is found to be very distinctly V-shaped in all the larger valleys. Thus, in the upper part of Glen Quoich it recedes northward for upwards of a mile, while in Glen Lui and Glen Derry the indentation apparently due to the valley is even more strongly marked. In Glen Dubh the V-shape is less conspicuous, as the glen is smaller and narrower. The southern boundary of the granite on the western side of Glen Lui is the Clais-na-Fhearna fault, and the rock is much crushed and intersected with quartz veins in the neighbourhood of the dislocation.

These facts suggest that in the deeper glens we are approaching the lower surface of the granite mass, and though no direct evidence of sill-like intrusion on a large scale has been observed, the probable form of the mass of granite on its southern side may be inferred to be roughly that of a cake or sill, with vertical or highly-inclined edges.

Around the margin of the granite, whenever a good section is obtained, minute veins of granitic material have been observed in the metamorphic rocks. These are sometimes fine-grained, with the component crystals interlocking with the crystalline constituents of the country-rock, but occasionally, especially where the veins are larger, coarse pegmatite and aplite have been noted. None of these veins have been traced to their parent source; but from their occurrence contiguous to the granite margin, and their similar composition, it may be inferred that they are offshoots from the main intrusion.

With regard to the metamorphic effects of the intrusion of the Cairngorm granite, MR. CUNNINGHAM-CRAIG reports that though the surrounding quartzose biotite-gneiss is not of such composition as to give very clear evidence of additional alteration by the younger igneous rock, a mass of felspathic gneiss, which is included between the Glen Derry diorite and the granite, is much more highly crystalline than the rock outside the granite area. Some granulite bands in this mass show such a high state of crystallisation as to simulate igneous material, and to suggest

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that "reconstruction" has taken place, more especially along those laminae the mineral and chemical composition of which was most favourable to alteration under thermometamorphic processes.

The most interesting evidence of change, however, is afforded by the band of limestone and black schist on the eastern side of Glen Lui and Glen Derry. The limestone appears on the north-western side of the Clais-na-Fhearna fault, at a distance of nearly a mile from the granite which is displayed on the western side of the glen. From this point the limestone can be traced north-westward, approaching the granite boundary obliquely to the east of Derry Lodge, where it probably comes in contact with the igneous rock, but the ground is there entirely obscured by drift for some distance. In Glen Derry, a mile to the northward the limestone is well seen in the burn section at Derry Falls, at a distance of less than 300 yards from the granite margin. In the Glen Lui section, the limestone presents the characters that commonly show themselves in an area which has not been very greatly affected by thermometamorphism; the purer bands are grey and bluish in colour and are not conspicuously crystalline, while the impure bands are soft and friable, contain much free carbonate and show no signs of conversion into hornfels. At the north-western part of the exposure, thin bands of tremolite-schist appear which probably represent the altered selvage of the limestone. A band of black schist folded with the limestone has apparently suffered greatly from shearing, and contains quartz "eyes" with garnets; certain bands are filled with rusty crystals of kyanite, while others show large irregular aggregates of andalusite, but the rock is everywhere highly schistose and friable. The kyanite, andalusite and garnet are most abundant towards the north-western extremity of the exposure, that is, in the direction of the main granite mass. In the Glen Derry section, where the granite must lie very near, though the actual junction is not seen, the limestone is represented by a mass of hard, beautifully banded calc-silicate hornfels, only the purest bands containing free carbonate of lime, which also appears to decrease somewhat in quantity to the northern extremity of the section. Thin bands of white saccharoid limestone containing aggregates of a pale flesh-coloured garnet are noticeable, while in the impure bands pale green hornblende, wollastonite, epidote, idocrase and malacolite (?) were detected by MR. CUNNINGHAM-CRAIG in the powder which he obtained by crushing samples of the rock, and which he examined under the microscope. His results have since been confirmed in a study of thin slices of the same rocks by MR TEALL, who has furnished the following notes of the microscopic characters of specimens taken from Derry Falls:—

"[8340.] Banded hornfels containing malacolite, wollastonite, alkali-felspar, sphene, quartz, and hornblende. The wollastonite occurs in radiating tufts and the felspar in granular aggregates and large irregular micro-poikilitic patches. The malacolite in certain parts of the slide also occurs in large micro-poikilitic grains."

"[8343] A mottled calc-silicate hornfels containing large patches of pale brown idocrase and garnet. The rock contains also malacolite and wollastonite." (Mr. Cunningham-Craig.)

"[8344.] White saccharoid marble containing brown spots and bands of idocrase and garnet. Wollastonite and malacolite are also present."

Though the black schist is not exposed at the section just referred to, some thin infolds of more argillaceous material which make their appearance, have to a great extent lost their schistosity, and appear as hard dark-coloured bands containing kyanite. The impure siliceous beds, which are here folded with the limestone, have had their bedding practically obliterated, so that there is some difficulty in observing their actual dip. This alteration in the mineralogical character of the calcareous band cannot reasonably be accounted for by a change in the composition of the material, for no direct evidence has been detected that such a change has taken place. The alteration is precisely what is ordinarily to be observed in rocks of this nature as they approach a large granitic mass. As no igneous intrusions other than the Cairngorm granite appear in the neighbourhood, the inference may be drawn that this conversion of the calcareous and associated rocks into hornfels and the development of the concomitant minerals that are characteristic of this type of thermo-metamorphism have been caused by the intrusion of the Cairngorm granite. In this connection it may be noted that in the hornfels area of Glen Ey and Corriemulzie, where the black schist is so distinctly affected by additional thermo-metamorphism (*Summary of Progress* for 1897, p. 53), the limestone bands do not show an alteration to calc-silicate hornfels such as that above described, and in fact do not seem to have been greatly affected mineralogically.

To the north of Braemar a sill of granite with accompanying subsidiary intrusions closely resembles in composition and in general appearance the Auchindryne granite which is exposed in and about Braemar, and the age of which in relation to the surrounding rocks has been for some time under consideration. This sill extends over the top of Creag a' Chleirich for upwards of a mile in a south-south-west direction, with a distinct dip to the south-west, and reaches nearly to the alluvium of the Dee valley. At its southern end, and again on the north-west side, the mass is bounded by fault-lines along which the granite appears to have been intruded. The sill is somewhat irregular in shape, and attains a thickness of nearly 100 feet. Exposures being plentiful, and easy of access, clear evidence has been obtained, not only as to the relative age of this intrusion, but also as to that of the compact quartz-porphyry sills of the unusual type characteristic of the Braemar district. MR. TEALL describes the rock of the southern part of the mass as a "medium-grained pink granite, comparatively free from ferro-magnesian constituents, and essentially composed of oligoclase, micro-perthite and quartz. Its alkali felspar is abundant, and occasionally shows a very fine microcline structure. Small patches of micropegmatite occur in it, and biotite is present in small flakes."

(Mr. Cunningham-
'raig.)

Though more acid in composition, the rock presents several of the features characteristic of the newer Highland granites; it has evidently been intruded since some of the north-east and south-west dislocations; the alkali-felspar is frequently moulded upon the quartz, and the biotites, when examined microscopically, are seen to contain the characteristic needles of apatite, which have been described as specially typical of the newer granite. By its composition, character, and appearance, this granite can be identified with the granite exposed in Auchindryne, immediately south of the Dee. The small sills and tongues associated with the Creag a' Chleirich sill show none of the protoclastic structures which have been observed in the minor intrusions associated with the Auchindryne sill, but the larger masses are almost identical, and cannot be distinguished as of different age on that account. In what follows, the Auchindryne sill and the Creag a' Chleirich sill will be spoken of together as the "Auchindryne Granite."

Traced south-westward the granite sill becomes finer in texture, and passes gradually into a sill of compact quartz-porphyry with chilled edges, identical with those sheets which so frequently appear in the area south-west of Braemar, and the age of which has not hitherto been determined. Specimens intermediate between granite and quartz-porphyry may be obtained, showing crystal groups included in a matrix, which becomes gradually finer to the westward, till, a quarter of a mile from the granite, the edge of the quartz-porphyry sill assumes the aspect of a fine flinty felsitic rock, containing a few small phenocrysts of quartz and alkali felspar.

Mr. TEALL has examined specimens from this "passage rock," which he finds to be rich in alkali-felspar with microcline structure; the matrix is often micropoikilitic, and the structure may be described as "half-porphyrific." The ground-mass of the quartz-porphyry sill to the westward is micropegmatitic, while a few small idiomorphic garnets occur in the chilled margins.

The Creag a' Chleirich sill is associated with numerous minor sills and tongues of granite, which are exposed on the hillside beneath the main mass, while thin granitic veins and strings become so abundant in places that the metamorphic rock may almost be said to be permeated with igneous material. These veins are sometimes coarse and pegmatitic, sometimes fine-grained; in certain places they show clean-cut junctions with the country rock, while in others there appears to have been an interlocking of the crystalline constituents of the igneous and metamorphic rocks, along the line of junction. The composition of the veins does not appear to vary greatly, but to be practically identical with that of the granite.

These veins and minor intrusions form another link with the phenomena already observed south of the Dee, especially in the Clunie section, where the similar tongues and veins only differ by usually exhibiting a faint parallel or "round-grain" structure. None of the tongues, veins or sills of granite material in the ground north of the Dee show any signs of parallel structure.

In Glen Slugain, north-east of Creag a' Chleirich, several intrusions of similar pink granite have been noticed, but they all occur at a low level and cannot be traced for any distance. To the westward of the Auchindryne granite no other plutonic rock appears at the surface till the Cairngorm granite mass is reached. That vast body of eruptive material lies, as already mentioned, on the farther (and apparently the upthrow) side of a large fault. Quartz-porphyrries, on the other hand, are very numerous, and may be traced in parallel sheets, sometimes for a distance of two miles along the hillsides. These sills have a low general dip to the south-west, and increase in number in that direction. The granite sill of Creag a' Chleirich also dips to the south-west, and here it may be pointed out that the granite intrusions appear to have a vertical as well as a horizontal limit; the granite is exposed on comparatively low ground, though rising to a height of 2,000 feet on the summit of Creag a' Chleirich, while the quartz-porphry sills to the westward are exposed at a height of over 2,500 feet, and on Creag Bhuilg, two and a half miles west-south-west of the granite, reach a height of over 2,000 feet. At a distance of four miles west of Braemar, the quartz-porphry sills are thinner, less numerous, and have evidently been more quickly cooled, while at a distance of four and a half and five miles westward they are represented by a few thin irregular felstone intrusions, of which the material resembles that of the chilled margins of the quartz-porphry sills. In the area to the south-west of Braemar the sills continue for a much greater distance.

From these observations it may be inferred that the igneous intrusion has taken place from the eastward and north-eastward, so that in passing westward we are receding from the parent source of the eruptive material, and coming into areas wherein the cooling of the thinner molten injections took place more rapidly. It is a significant fact that in thus moving westward we pass from an area of hornfels-alteration into one where no proofs of additional thermometamorphism are forthcoming.

In the course of the survey of the ground north of the Dee, it has been observed that argillaceous and calcareous rocks, which are seen in contact with the Creag a' Chleirich granite sill, have been intensely altered by that intrusive sheet, the black schist being converted into a compact hornfels, and the calcareous beds being altered to a hard, banded, calc-silicate rock.

Evidence of faulting is well-marked in the area north of the Dee; the Glac Anthon fault has been traced to the north side, where it apparently splits into two dislocations, the principal one making a very deep gully (Clais a' Chait) in the ridge between Glen Slugain and the Dee Valley.

Reference has already been made to the Clais-na-Fhearna fault, which brings up the limestone on its north-westward side and forms a very wide and deep gash in the hillside between Glen Lui and Glen Quoich. There are many subsidiary faults and crushes branching from and parallel to this great line of movement, and the rocks are veined and shattered for some

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distance on either side. Part of the movement along this line of dislocation has taken place since the intrusion of the Cairngorm granite, which on the western side of Glen Lui forms the north-western face of the fault, and is full of veins and minor crushes in its neighbourhood.

(Mr. Hinxman.)

Though MR. HINXMAN was not engaged last year in mapping any portion of the Cairngorm granite, he has examined so much larger a tract of it than any one else that it has been thought desirable to obtain from him a brief statement of his experience in tracing the relation between the intrusive mass and the surrounding rocks, and to insert this statement in the present *Summary of Progress*, together with the reports of his two colleagues. He remarks that the effects produced by the Cairngorm granite have been found by him to be most marked in the regions occupied by the rocks of the Banffshire series, which had undergone far less previous alteration than the schistose rocks to the west of them. In the western Cairngorms and the Monadhliath Mountains the granite was intruded into rocks that were already in a high stage of crystallisation, and the schists and gneisses of Upper Strath Spey consequently show little or no alteration compared with that produced on the less modified slaty schists and limestones of Banffshire and Aberdeenshire.

The limestones of Glen Avon, though fairly crystalline in character throughout, show increasing metamorphism as they approach the granite. Marmorosis, and the conversion of the impurer portions of the rock into tremolite and malacolite-rock, and malacolite-hornfels (slides 5454, 5456 and 5449 of the Geological Survey Collection) can be observed along the left bank of the Avon at Inchrory, in Glen Builg, on the slopes above Loch Builg, and in Glen Loin in the Glen Avon Forest.

Mineralization, including the production of garnet (green and brown), idocrase and other contact-minerals, is best seen in the small inclusions and outcrops that are found within and close to the granite on the Baddoch in the Braes of Abernethy, on Ben Avon, and in Glen Gairn. At the last-named locality patches of highly mineralised limestone occur within and along the margin of the area of tonalite that has been regarded as a more basic portion of the Cairngorm granite intrusion.

The band of mica-schist that runs south-east from the Caiplich Water to the Linn of Avon affords an example of progressive metamorphism due to the Cairngorm granite. Starting as a fine-grained, flaggy mica schist or phyllite, it becomes more crystalline and gneissose in character as it approaches the granite, until at the Linn, where it forms a narrow tongue almost enclosed by granite, it passes into cordierite-gneiss.

The "black schist" along the edge of the granite in Glen Builg, and on the hillside above Loch Builg, shows alteration of the hornfels type. Similar alteration is seen at Knockan and Nethertown in Glen Livet, where the black schist approaches the Glen Livet granite mass. Mention may also be made of the

development of large crystals of andalusite and staurolite in the black schist of Glen Tervie near the edge of the Ben Rinnes intrusion, an outlying mass of the Cairngorm granite. These crystals have been developed since the last movements that produced the "puckering" of the schists. (Mr. Hinxman.)

Inverness-shire.

The region of Badenoch, in the upper part of the wide basin of the Spey, has been further surveyed during last year by MR. HINXMAN, who has found there the usual metamorphic rocks of the Central Highlands, with their associated igneous intrusions. His continued examination of the area of Glen Truim, along the upper course of the Spey, and in the Monadhliath mountains to the north of that river, has shown that the two types of rock described in former *Reports* are still persistent over a wide area, and can be readily differentiated. Broadly characterised as (1) Muscovite-biotite-gneiss and (2) Flaggy quartz-biotite-granulite, they present several further local variations. The former type includes garnetiferous mica-schist; "spangle"-schist in which white mica occurs in large scattered crystals lying at an angle to the planes of foliation; and coarse gneiss with crumpled folia, in which biotite is the predominant mineral. The quartzose series varies from a fine-grained granulitic biotite-gneiss, of which the black mica is an abundant constituent, to a highly siliceous flaggy schist or quartzose flagstone. (Strathspey. (Mr. Hinxman.)

Two systems of plication appear to obtain in this area. The rocks have been subjected to rapid isoclinal folding, and, in addition, have been thrown into a series of wide undulations that often lie at a very low angle. This complicated structure renders it difficult to determine the relative position of the rocks to one another in the area under consideration.

Evidence was last year obtained of the continuation of the Loch Ericht fault along the course of the River Truim. This powerful dislocation, which shifts the outcrop of the Moor of Rannoch diorite near Loch Tulla for upwards of two miles, and has determined the position of the hollows occupied by Loch Laidon and Loch Ericht, enters the valley of the Truim a short distance below Dalwhinnie Station. The breccia and other signs of fracture, seen at several points along the course of the stream above Crubanmore and below Etteridge Bridge, indicate the position of the fault as far as the Bridge of Truim; its further course being concealed beneath the wide alluvial stretches of the Spey.

Several sills of the Glen Tromie porphyry have been observed by MR. HINXMAN in the lower part of Glen Truim, and one has been mapped by him on the slopes of Tom dubh-glaic in the Monadhliath range, the first observed occurrence of this rock to the north of the Spey. These sills are, as a rule, similar in character and composition to the porphyries from Glen Tromie, described in detail in the *Summary of Progress* for 1897. In

Strathspey.
(Mr. Hinx-
man.)

one of the Glen Truim sheets, however, the phenocrysts of quartz and felspar are sometimes entirely absent, and the rock becomes in parts completely felsitic.

The opinion expressed last year (*Summary of Progress* for 1897, p. 56) that these quartz-porphyry sills represent the later phases of the Cairngorm granite intrusion, has been strengthened by the evidence obtained this year in Glen Truim. The veins of coarse muscovite-pegmatite, so abundant in the schistose rocks in that district, are distinctly cut by the quartz-porphyry sills; and therefore, whatever may be the relation in point of age of these pegmatites to the Cairngorm granite, they are prior to the intrusion represented in this region by the quartz-porphyry.

An acid igneous rock, showing remarkably fine spherulitic structure, has been mapped along the summits of Carn Dearg Mor and Sgorr Dearg, the high ridge lying between Glen Feshie and Glen Bhuran. The rock is bright-red in colour, and generally felsitic in character, but often contains small dihexahedral crystals of quartz. The spherulites can hardly be detected under an ordinary lens in the fresh rock, but weathered specimens can be obtained in which they stand out in high relief, and present a most striking appearance. This felsite, as well as other small intrusions of a similar rock on the east side of Glen Feshie, often present a banded appearance, due, no doubt, to flow-structure.

The examination of these felsites under the microscope by MR. TEALL, shows that they contain no ferro-magnesian minerals, and have been formed from a very pure quartzofelspathic magma, resembling that which under different physical conditions, has given rise to pegmatites. When phenocrysts are present, which is by no means always the case, they consist of quartz, turbid felspar, and micro-pegmatitic intergrowths of these two minerals; similar to those observed in the Tertiary spherulitic felsites of Druim-na-Eidhne in Skye. The quartz-phenocrysts occur as bipyramidal crystals and corroded grains. The spherules are rather less than 1 mm. in diameter, and usually have a light-coloured core with a darker periphery, but show no radial structure.

It may be worth noting that microscopical examination of a specimen from a thin vein of Cairngorm granite, close to the edge of the main mass in Coire Garbhach, has revealed the presence of abundance of fresh microcline in conjunction with turbid oligoclase, quartz and biotite.

Lamprophyre sills, of a later date than the acid intrusions, are abundant among the schistose rocks of Badenoch. They frequently occur at the base of the steep isolated crags so common in this district, and seem by their superior hardness to have tended to determine these prominent features.

Certain thin sills of much decomposed basic rock found in the quartz-schists on the east bank of the Spey at Aikenway (Sheet 85 of the one-inch map) have been identified under the microscope as typical camptonite.

Perthshire.

Besides the ground surveyed by him in Deeside already described, MR. CUNNINGHAM-CRAIG has continued, during part of the working season, the survey of the region of Strathyre and the Trossachs. The stratigraphical succession reported by him in the last *Summary of Progress* (p. 57), for this part of Perthshire, has been found to hold good over all the ground that has since been mapped. The various groups of that succession preserve their lithological characters with little change over wide areas, though there appears to be some local thickening and splitting up of the coarser grits.

The Aberfoil slates, which are well seen about the foot of Loch Lubnaig, consist of several bands, alternating with fine gritty beds, which show an indistinct cleavage; each slate-band can be distinguished by its colour, thickness, and the lithological characters of the beds with which it is associated. There is no evidence of repetition by folding.

To the south-east of the slate-bands, and apparently below them, grits of a totally different character from those to the north-west are observed. One of them, containing felspar and quartz pebbles in a fine chloritic matrix, has been examined by MR. TEALL, who describes it as composed of "large quartz and felspar grains in a fine schistose matrix. The grains of quartz and felspar (oligoclase) are often much crushed and granulitized. The matrix is a fine-grained aggregate of chlorite, sericite and quartz, with some iron ores and leucoxene(?)." The rock is "markedly less crystalline than some chloritic and epidotic grits from the north of Ben Ledi," which were examined at the same time.

The green grits have been traced continuously from the Balquhiddy district to Loch Katrine, and also mapped in an outlier on the western side of Loch Lubnaig. They show very little change in character in this area, though it has been noted that fine schistose chloritic beds are more numerous in the south-western part, where they replace, to a certain extent, the coarser epidotic grits, which are well seen near Loch Lubnaig, especially in the upper part of the group. Small ill-defined yellowish green knots or nodules, and strings or folia of similar material are sometimes observed, while thin veins or bands of massive chlorite occur more rarely.

MR. TEALL has examined several specimens from the ground north of Ben Ledi, and the following descriptions are taken from his notes: "(8227). Irregular grains of quartz and plagioclase in a matrix of sericitic mica, chlorite, epidote, and some turbid indeterminate material." In a coarser grit (8228), "the quartz-grains often show peripheral granulation, and thus tend to merge themselves in the crystalline matrix." A still coarser grit contains large grains of quartz and plagioclase: (8229). "The large felspars, one of which gave the reaction of oligoclase in the flame, are more or less granulitized." (8230) is "a dark fine-grained rock, traversed by thin yellowish-green bands or folia of

Strathgryre
and the
Trossachs.
(Mr. Cunningham-
Craig.)

epidosite. The fine-grained bands are an aggregate of epidote, chlorite, white mica, granulitic quartz, and felspar, with sphene as an accessory. The light yellowish-green bands are formed of epidote, quartz, and a few large flakes of biotite." MR. TEALL describes these crystalline epidotic grits as similar to rocks which he has examined from the Cowal district, and he notes that "the elastic character of the rocks is very obvious in the coarser-grained specimens, but becomes much less so in those which are finer-grained, and finally ceases to be recognisable."

Small intrusions of felstone and lamprophyre have been observed occasionally in this area; the lamprophyres increase in number in Glen Gyle, while felstones are more numerous about the eastern end of Loch Katrine and in Glen Finglas. Dolerite dykes are rare, but can occasionally be traced for great distances.

The mapping of the "Green Beds" north of Loch Katrine has revealed a remarkable change in the character of the folding, and has made clear the structure of the district. A large trough has been traced from the Balquhiddar area, where the folding is simple and undulating, to Loch Katrine. This trough brings in the epidiorites, a sill of which is exposed in the centre of the trough on the watershed between Glen Dubh and Glen Finglas. In the south-western part of the area the eastern limb of the syncline is found to be inverted, while the dips become steeper and the folds more closely packed, till finally, on the shores of Loch Katrine, east of Brenachoil Lodge, the folding becomes vertical and isoclinal. The structure in the eastern part of this area is further complicated by a series of north-east and south-west faults, which, in conjunction with the steeper folding have the effect of repeating the outcrop of the Green Beds three times in the burn-section in Glen Finglas.

The Glen Ample fault, with several subsidiary dislocations, has been traced for three miles on the western side of Loch Lubnaig, the slate-bands showing very clearly the effect of each dislocation. There appears to have been some horizontal movement along this line of discontinuity, as shown by slickensides, and the apparent dragging of nearly vertical slate-bands on the eastern or upthrow side, horizontally into the line of fault.

Argyllshire.

Loch Awe
and Glen
Etive. (Mr.
Kynaston.)

In Argyllshire considerable tracts of the younger or Dalradian schistose rocks have been mapped during the past year. MR. HILL, as already mentioned, returned for a short time to his former ground in the Loch Awe district, but met with no new features of sufficient importance to require mention here. Further to the north small tracts of the same rocks were mapped by MR. KYNASTON, but except with regard to the phenomena of contact metamorphism, which will be fully considered in a later section of this *Summary* (p. 82), he encountered no new facts of note. He found the Loch Awe and Ardrishaig series to maintain their normal and characteristic features in

the tract between Dalmally and the Cladich Burn, and as on the opposite side of Loch Awe, to appear frequently in a very unaltered condition. They include numerous hornblendic sills which show considerable petrological variation. Small sills are also occasionally met with consisting mostly of fine-grained more acid rocks, sometimes porphyritic. These, MR. KYNASTON believes, belong to the great series of porphyrite dykes and sills associated with the Ben Cruachan granite.

Loch Awe
and Glen
Etive. (Mr.
Kynaston.)

In the Glen Etive district the same observer has again had occasion to map some of the younger schists while working a part of the ground to the west and north-west of the Glen Etive granite, lying between Glen Etive and the upper portions of Glen Creran and Glen Ure. Here, however, the condition of the schists is in marked contrast with those of Loch Awe side. They show altogether a much greater degree of crystallisation and schistosity, which does not become appreciably lessened as they are traced away from the granite. Evidently they had been much more affected by the forces of the so-called dynamo-metamorphism, which, as it were, left their imprint upon them previously to the intrusion of the Glen Etive and other newer granites. The fact is here again exemplified that earth-stresses which determined the structure of the ground have acted with increasing intensity from the more south-western portions of Argyllshire in a general north-easterly direction.

The schists to the west of Glen Etive may be divided provisionally into the following groups:

(1). *Massive white quartzites*. A white or greyish tough quartzite, sometimes pinkish, and often slightly banded or laminated. This group is especially well developed on the northern and southern flanks of Beinn Fhionnlaidh, and in Allt Charnan. It is also occasionally met with as inclusions in the granite. The quartzites are succeeded by

(2). *Quartzose and biotite-schists*, well exposed on the southern slopes of Beinn Fhionnlaidh, and other places. Here may also be included some pinkish gneissose micaceous schists (with two micas), which succeed the quartzose and biotite-schists, and are well developed in the upper portions of Allt nan Gaoirean. These rocks undergo the hornfels type of alteration along the granite margin. Next to these by gradual passage, come

(3). *Garnetiferous mica-schists*, — pale silvery-grey, markedly foliated rocks, well-developed at the head of Glen Creran, and in the corries at the head of Allt Charnan.

All these sedimentary materials are frequently found to be traversed by sills of porphyrite, as was also so frequently found to be the case in the districts bordering the Ben Cruachan granite further to the south west. The older hornblendic (epidiorite) sills are, however, rare in the Glen Etive area.

A more detailed description of some of the schists just enumerated will be given in a later Section of this *Summary*, devoted to the contact metamorphic phenomena around the great granite masses of Ben Cruachan and Glen Etive (p. 76, *seq.*).

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In the districts bounding the head of the Linnhe Loch, MR. GRANT-WILSON has extended his previous survey on the west side by mapping the ground as far south as Glen Scaddle, and as far north as Gairlochy, while on the east side he has examined the lower part of the Great Glen, and the hills on the south side of the lower or western end of Glen Novis. The important dislocation which runs along the line of the Great Glen passes through the middle of his area.

In the basin of Loch Eil the "gneissose flagstones," referred to in last *Summary*, continue across the district surveyed last year, dipping S.E. and S.S.E. at an average angle of between 20° and 30° , though to the west of Fassafarn they become more contorted. Similar rocks extend northwards beyond Glen Loy, but dip there to S. and S.W. Between that glen and Loch Lochy they are intersected by numerous dykes and veins of pink granite.

Some large and hitherto unrecorded masses of intrusive rock have been met with piercing the flagstones. One of these, which has not yet been completely traced out, forms an irregular oval, three miles long by two and a half broad, stretching across Glen Scaddle and is seen in section in the river Scaddle. As far as yet examined, it consists of a core of epidiorite with an outer margin of a more acid material, all more or less foliated. In texture the epidiorite varies from coarse to medium, and it is generally of a dark grey colour. A specimen taken from the river Scaddle, half a mile below Creag Bheitheachain, has been sliced and examined by MR. TEALL, who reports as follows regarding it:—

"[8233.] Medium-grained rock composed of colourless plagioclase and a dark green mineral. Under the microscope it is seen to be essentially composed of basic plagioclase and fibrous or uralitic hornblende. Chlorite and iron-ores are also present. The plagioclase floats in the diffusion in a dense zone slightly above labradorite and well below oligoclase. It belongs to the labradorite-andesine series. This rock has the structure and composition of epidiorite."

A large number of hill streams fall into the river Scaddle and these, with the fine cliffs of Creag Bheitheachain and Choire Bhulg afford numerous exposures of this rock. From a number of observations the general direction of the foliation in this epidiorite was found to vary from 15° to 25° west of north.

Near the foot of the glen at the Eas Dubh fall, and at its western boundary on the slopes of the Druim Leathad nam Fias, this epidiorite is surrounded by a zone of granulitic gneiss from 150 to 300 yards in breadth, which appears to be wholly or in part composed of foliated igneous materials. At the falls where a good section is exposed the relation of this gneiss to the epidiorite on the one side and the flagstones on the other is clearly seen. The junction with the epidiorite is a vertical wall, and a similar boundary may be seen also at the western edge of the epidiorite above Creag Bheitheachain. As the falls are approached from the east the flagstones are observed to become more baked and twisted, until from the foot of the falls for 130 yards they are traversed by intrusive dykes of this acid gneiss, which in many cases cross their lamination at a slightly oblique

angle. Above the falls a belt of light brown, fine-grained gneiss 70 yards broad contains numerous included fragments of gneissose flagstone, which vary in size from a few cubic inches up to several cubic feet. The inference that the gneiss is of igneous origin is strengthened by the microscopic examination of a specimen from this locality, examined by MR. TEALL, who has supplied the following description of it:—

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"[8,235] A light coloured, banded, granulitic gneiss. Under the microscope it shows turbid plagioclase felspar, fresh microcline and quartz (very abundant). The quartz and microcline form a foliated aggregate in which the turbid felspar occurs as phenocrysts without crystalline form. Biotite and sphene occur as unimportant accessories."

In the river Scaddle above and below Creag Bheitheachain the epidiorite is cut by dykes of basic rock with zoned plagioclase-felspar crystals. These dykes are even more foliated than the surrounding rock and now form hornblende-biotite schists. A fine grained specimen of the massive dyke below the cot house of the "Creag" is described by MR. TEALL as:—

"[8,236] Fine-grained dark-grey foliated granulitic rock. Under the microscope it shows a foliated aggregate of plagioclase, biotite and hornblende, with some quartz, sphene, and iron-ores, as accessories. Viewed with ordinary light the rock appears to be an ordinary hornblende-biotite-schist, but under crossed nicols the plagioclase is seen to be zoned. The central core extinguishes at a different angle from the periphery. There is moreover a tendency to the lath-shaped form. This peculiar structure differentiates the rock from the normal schists, and I am inclined to regard it as igneous."

The epidiorite, the zone of granulitic gneiss, and the hornblende biotite-dykes are alike traversed by numerous dykes and veins of porphyrite, which, however, are most numerous, within the epidiorite area. They are all more or less foliated, and where included within the epidiorite they are always more foliated than the surrounding rock. These aplite dykes are generally light in colour, contrasting strongly with the darker epidiorite. A specimen taken from one, four yards broad, cutting the epidiorite in the River Scaddle half a mile below Creag Bheitheachan, is thus described by MR. TEALL:

"[8,234.] A light-coloured, medium-grained porphyritic rock. Examined with the microscope it shows phenocrysts of zoned plagioclase (in part oligoclase) in a matrix of micro-crystalline quartz and alkali felspar. The outer zone of the phenocrysts belongs to the same period of consolidation as the ground-mass. Ferro-magnesian minerals are very scarce and are represented by biotite, often replaced by chlorite. Sphene occurs as an accessory. The rock may be termed a porphyrite."

From MR. TEALL's description of the igneous granulitic gneiss and porphyrite dykes of Glen Scaddle, it will be seen that they bear a close resemblance to one another, so far as composition is concerned.

To the south of Glen Scaddle, and on the steep craggy slopes of Beinn na Cille, that stretch downwards to Loch Linnhe, several foliated diorite dykes traverse the flagstones of this hill. In all probability they emanate from the Glen Scaddle igneous mass.

Since all these igneous rocks here described as part of the Glen Scaddle network are foliated in a direction common with the

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general foliation of the surrounding rocks, it is evident that they have all been intruded prior to, or during, the movements which produced the foliation of the district. Partly for this reason, and partly on account of their petrological relationship, the various intrusions which cut the epidiorite may be considered not improbably to mark successive injections from the same original magma, which gradually became more and more acid as its more basic constituents separated out.

Another important mass of somewhat basic material, having an intrusive origin, lies directly to the north of the Banavie granite mass, and has been traced for a distance of three miles up Glen Loy. Its outline is very irregular, but its average breadth north and south of the river Loy is about one mile. As shown in the excellent section cut by the river, the rock in general consists of a medium-grained steel-grey diorite with lath-shaped and prismatic hornblende crystals, but in some places, as in the main stream below Inverskilavulin, becomes much coarser and includes large bladed crystals of hornblende. An average specimen of this rock taken from where the north Dubh Chlaise joins the river Loy was analysed by MR. GRANT WILSON, and gave the following result :—

SiO ₂	...	...	...	...	...	43·84
TiO ₂	...	...	...	...	...	·27
Al ₂ O ₃	...	...	...	...	...	24·64
Fe ₂ O ₃	...	...	...	...	...	3·97
FeO	...	...	...	...	...	6·73
MnO	...	...	...	...	...	·29
CaO	...	...	...	...	...	10·24
MgO	...	...	...	...	...	4·95
K ₂ O	...	...	...	...	...	·99
Na ₂ O	...	...	...	...	...	2·58
Loss on Ignition	...	...	...	...	...	1·83
						100·33

From the chemical composition thus exhibited the rock is therefore a gabbro-diorite. A specimen similar to that analysed was taken from the river 200 yards above the bridge of Loy, and sliced for microscopical examination by MR. TEALL, who reports regarding it—

"[8289.] Under the microscope, hornblende, biotite, plagioclase, iron ores including pyrite and apatite. Epidote and chlorite as secondary products.—The rock is a diorite."

At the Tom an Eildean ridge, the edge of the diorite is very coarse, some of the crystals of hornblende measuring over two inches in length. MR. TEALL describes the rock as follows :

"[8290.] Extremely coarse-grained aggregate of hornblende and plagioclase (1—2 cms.). The rock is a diorite-pegmatite. Under the microscope, plagioclase, hornblende, and a little biotite, with some secondary chlorite."

Below the bridge of Loy the fine-grained edge of the diorite mass is seen in contact with baked micaceous schist, both being cut by thin red granite veins. On the north side of Gley Loy

also the junction between the diorite and the granulitic flagstones is well exposed both on the driftless hill-slopes and in the numerous streams that flow down their sides. For some distance outward from the contact, the flagstones are baked and altered and become gneissose. District of
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The Coire an Light uinn Burn crosses the boundary line of the diorite several times. The banded flagstones are broken and indurated, and together with the igneous rock are cut by numerous small red granite dykes.

A description of the Banavie granite was given in the *Summary of Progress* for 1897. A sample of this rock from the Strone quarry has since been analysed by MR. GRANT-WILSON, with the following results:—

SiO ₂	...	...	...	...	...	76.71
Al ₂ O ₃	...	...	...	...	...	11.68
Fe ₂ O ₃	...	...	...	...	...	1.01
FeO	...	...	...	...	...	1.5
MnO	...	...	...	...	...	.09
CaO	...	...	...	...	...	.44
MgO	...	...	...	...	...	.16
K ₂ O	...	...	...	...	...	6.65
Na ₂ O	...	...	...	...	...	.80
Loss on ignition	...	...	...	...	...	.61
						99.65

This granite about twenty years ago was worked to a considerable extent at the Strone quarry. A specimen of it sent to MR. TEALL was examined by him microscopically and he describes it as:

"[8291]. Pink, medium-grained granite with a few flakes of biotite. Under the microscope oligoclase, microcline (very abundant), quartz and biotite (very scarce). The rock is a microcline-granite."

The main mass of Banavie granite bounds the Glen Loy diorite on its south side. The junction line between the two rocks is very irregular, and the granite sends great tongues into the more basic mass. Beyond the contact boundary the diorite is traversed by numerous dykes of granite.

Above the Bridge of Loy several large and small pink granite dykes cut the diorite with a general north-east course. From one of these, 300 yards above the bridge, a specimen was submitted to MR. TEALL, who reports regarding it:

"[8292.] Medium-grained pink granitic rock, almost entirely composed of quartz and felspar. Under the microscope microcline, quartz, and biotite (scarce). The rock contains a little vermicular pegmatite. There may be a little original muscovite. It is a microcline-granite."

For about a mile-and-a-half above the Bridge of Loy these pink granite dykes are very numerous. The acid material sometimes takes the form of sills. The diorite is here also intersected by numerous veins of pegmatite, lighter in colour than the material of the granite dykes, much coarser in texture, and often presenting badly defined irregular margins. A specimen from

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one of these pegmatite veins from the foot of the Allt Barraich, Glen Loy, examined by MR. TEALL, is thus described by him :

"[8293]. A nearly white rock, containing small scales of muscovite. Under the microscope appear oligoclase, alkali-felspar, including microcline, quartz, and muscovite, magnetite as an accessory. Alkali-felspar, quartz, and muscovite often occur in large plates, showing micro-porphyrific structure and quartz and alkali-felspar sometimes show micropegmatitic structure—the rock is a muscovite-granite."

The close resemblance of the determinations by MR. TEALL of the Banavie granite, the pink granite dykes, and the pegmatite-veins cutting the diorite, together with the direct evidence afforded by the Glen Loy sections, show the granite to be of later origin than the more basic rock, and indicate that the granite dykes are apophyses from the main mass. The Banavie granite, the Glen Loy diorite, and its granite-dykes are all unfoliated.

An interesting feature of the ground surveyed by MR. GRANT-WILSON last year is the occurrence of dykes of the Scourie type in the flagstones on the ridge of the Coille Mhor of Fassaferrn. One of them, 18 yards broad, which has an easterly course, and stands out in bold relief above the surrounding flagstones, is hard and tough, dark-grey—almost black—in colour, and studded with rough aggregates of hornblende, some of which are more than a quarter of an inch in length. A specimen of this rock, examined by MR. TEALL, is thus described by him :—

"[8199]. Under the microscope green hornblende in large ragged poikilitic patches and aggregates of smaller individuals, granulitic plagioclase, iron-ores, and sphene. Original structures obliterated. This dyke is of the Scourie type—epidiorite."

These dykes appear to be earlier in age than the other varieties that traverse the flagstones. They may be related to the Glen Scaddle mass. Several other hornblende-schist sills (some with garnets) were mapped in the flagstone area. These probably belong to the same period, with the dykes just referred to. In addition to the numerous red granite-dykes, several red and grey felspar-porphyrries are seen in the Annet Burn, and also along the ridge of the Druim Fada.

East of the line of the great fault that coincides with the chain of lakes and the long hollow of Glen Albyn, MR. GRANT-WILSON continued the mapping of the zones of schist traced by him between Fort William and Loch Leven, and followed them northwards across the tract between the Ben Nevis mountain group and the rivers Spean and Lochy. These zones consist of (1) Sericitic mica-schist, (2) Black schist, (3) Dark-grey flaggy mica-schist, (4) Limestone, and (5) Black Schist.

(1.) The most westerly portion of the strip of sericitic mica-schist near Camisky is generally green in colour and garnetiferous, and includes deformed strings and masses of black-schist and quartz-schist. In the continuation of this zone to the south of Fort William, the best examples of the rock are to be found

along the Auchintore shore, a specimen from which is thus described by MR. TEALL:

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"[6241.] A fine-grained greenish-grey schistose rock. Under the microscope, quartz, felspar (partly striated), sericite and chlorite; iron ores and a carbonate as accessories. Some of the large grains of quartz and felspar appear to be clastic fragments. I think the rock is a sheared fine-grained grit."

The streams and craggy ridges above Auchindaull, about two miles S.W. from Spean Bridge, give good exposures of this crumpled and contorted schist, but the best section in the district is to be found in the rock gorge of the River Spean above Gairloch, which is not yet completely surveyed.

(2.) A belt of black schist varying in breadth from 150 to 400 yards lies between the sericite-schist, just mentioned, and the flaggy mica-schist. At a distance of 300 yards from the edge of the Ben Nevis granite this belt is exposed in the stream above the Ben Nevis distillery, where the rock is metamorphosed by the granite into a dark-grey banded hornfels. Traced to the north, away from the intrusive mass, the rock becomes less altered. At the back of New Inverlochy Castle it is still permeated with small dykes of granite, while below Auchindaull it contains knots and garnets.

(3.) The River Spean, between the Free Church of Killmonivaig and Roy Bridge affords an admirable section of the zone of dark-grey flaggy mica-schists. Owing to deep drift between the Spean and Fort William, only isolated rock sections are exposed in that part of the district. Along the course of the River Lundy, which runs at no great distance from the margin of the granite, these mica-schists are seen to be much altered. They have been converted into hornfels.

(4.) The band of limestone is an extension of that which has been traced in a continuous line (except where intersected by Loch Leven and the Appin Ferry) from the south point of Lismore to Glen Nevis. In the tract between Fort William and the Spean it extends from Creag Aoile to Lianachan, and a traverse of the ground showed it to be continuous into Glen Roy, whence it probably stretches much farther to the north-east. It is well exposed at the Creag Aoile, where it appears as the purest crystalline limestone that has yet been met with during the Geological Survey of the Argyllshire Highlands. Almost entirely free from any admixture of black-schist, it is generally light grey in colour, with white bands. It more closely resembles the Appin limestone than that of Lismore. The planes of foliation in it are inclined at a high angle to the north, and its apparent breadth at the surface may to a certain extent be due to folding. To the south-west of Creag Aoile the limestone abuts directly against the granite, but probably on account of the purity of the rock, the contact minerals appear to be absent.

(5.) Of the second zone of black schist only a portion has yet been mapped. In the east Allt-Criche Burn a band of grey slaty phyllite comes next to the limestone. It is succeeded by a small belt of limestone, after which the black schist sets in,

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regularly foliated, and dipping to the south-east. This schist is cut by several dykes of granite, felspar-porphry, and lamprophyre, and passes into the condition of flinty hornfels.

Besides mapping the triangular space between Ben Nevis, the Spean, and the Lochy, MR. GRANT-WILSON was able to devote some time to ground situated to the south-west of Ben Nevis, in continuation of his previous survey of the district lying further to the south. He had already traced the northern limb of a synclinal fold of the limestone which stretches north-eastward from Corry Churachan, two miles north of Corran Ferry, to Beinn Riabach, two miles south of Fort William. Round this last-named hill the limestone forms steep crags, which overlook Glen Nevis, and folding upon itself it then turns round to the south-west, passing through Blarmachfoldach to the water of Kiachnish. In this district it is thrown into three synclinal folds, the centres of which are occupied by black schists. From the Coire a Mhuilinn, where the limestone passes below the black schist by the base of Sgor Chalum to the River Nevis, the rock presents an almost continuous outcrop. In Glen Nevis, at the surface, it is only separated from the granite of that glen by a narrow terrace of alluvium. To the west of the Water of Kiachnish, on both sides of the synclinal fold, the rock appears as an ordinary crystalline limestone. At Blarmachfoldach, two and a half miles from the Ben Nevis granite, small crystals of actinolite first show themselves in a band of impure limestone. Nearer to the granite, as was stated in the last *Summary*, the limestone is still further altered, and a specimen taken from the crags above Glen Nevis House was found by MR. TEALL to be "a light grey hornfels, containing some large crystals of hornblende."

The limestone is succeeded to the south-east by a considerable area of black schist, of which good sections may be seen in the water of Kiachnish, in the Coire a Mhuilinn, and on the rocky slopes of Sgor Chalum. In these exposures the strata have a north-east and south-west strike, and are generally either vertical or inclined at a high angle to the south-east. They consist mainly of black schist with occasional bands of phyllite. To the east of Lundavra these rocks pass latterly into the grey and green phyllites with black schist partings, which have already been mapped to the shores of Loch Leven, around North Ballachulish. The north-eastern corner of this area of black schist abuts against the Ben Nevis granite, while its south-western margin surrounds the granite boss of Meall a Chaoruinn. The contact metamorphism around these two igneous masses is very remarkable.

In the stream-sections midway between these two granites, the black schist is little altered, though the various dykes which intersect it are there numerous. In the course of the Kiachnish Water the rocks become more altered as they approach the granite of Meall a Chaoruinn. Some of the bands become knotted schists, while others are filled with small garnets. A specimen taken from the river below Blar a Chaoruinn, about

400 yards from the edge of the granite is thus described by MR. TEALL: District of
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"[8277.] A dark grey banded rock. Under the microscope it presents a confused aggregate of nearly colourless mica and micro-crystalline quartz, together with biotite, andalusite, and opaque grains, which appear white by reflected light (leucoxene)."

A similar progressive metamorphism is also to be seen as the black schist approaches the Ben Nevis granite. To the south-east of the vitrified fort, the schist becomes a dark, massive, well-banded steel-grey rock, which is hard to break. On the surfaces of the foliation planes mica is assembled in spots and masses. A specimen submitted to MR. TEALL was found to be:

"[8278.] Mainly composed of biotite and quartz. The biotite occurs in extremely small scales, and also in large irregular plates with pleochroic halos. There is also sericitic mica, chlorite, pyrite, and a few small crystals of tourmaline.—Biotite Schist."

The western edge of the Ben Nevis granite mass has now been traced from a point near Glen Nevis House north-eastward to the Sgor a Pheanais, a distance of six miles. It coincides generally with the line along which the different hills and ridges that form the mountain mass of Ben Nevis sink into the plain. Half a mile above Glen Nevis House the intrusive character of this granite is well seen in horizontal sections in the rocky bed of the river. The flaggy mica-schists are there intensely altered and shattered. The granite is steel-grey in colour, with flecks of black mica, but weathers rusty-red. So far as it has been mapped the rock is all unfoliated. It is medium in grain, but towards its edge it becomes fine-grained. A specimen taken from the hill above this section is thus described by MR. TEALL:

"[6561.] Medium-grained, grey granite. Under the microscope zoned plagioclase, orthoclase, quartz, biotite, and green hornblende are seen. Brown sphene, iron-ores (scarce), and apatite as accessories. Pleochroic halos round indeterminable inclusions in biotite. The feldspars and quartz all lie between sp. gr. 2.65 and 2.56. The zoned plagioclase probably ranges in composition from andesine or possibly labradorite to oligoclase, and agrees on the average with a somewhat basic oligoclase. It is markedly idiomorphic, and is the dominating feldspar. Quartz and orthoclase occur as interstitial matter. The margins of some of the plagioclase crystals contain vermicular quartz. Hornblende is pale-green in colour, and not very abundant. The granite is closely allied both in structure and composition to the granites of the Galloway region. The rock is a biotite-granite with some hornblende."

Another granite mass forms Meall a Chaoruinn (2,941 feet), which rises three miles south-west from the western edge of the Ben Nevis granite, and near the head waters of Kiachnish Water. This height, with its red screes standing out in bold relief against the white quartzite ridge of Stob Ban, forms a conspicuous feature in the landscape. The rock, which is everywhere unfoliated, is pink in colour, and varies from a medium to a coarse grain. It is largely composed of quartz and alkali-feldspar, and contains a few flakes of muscovite. Examined by MR. TEALL, it was found to consist of "[8276] Oligoclase, alkali-feldspar (micro-perthite), and quartz. The rock is mainly

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composed of alkali-felspar and quartz. It is almost a binary granite. The quartz contains liquid inclusions, with moving bubbles." He adds that this is the most acid granite that has as yet been obtained from this series of eruptive rocks. The outline of the mass forms an irregular square, with rounded corners, embracing about a square mile and a half.

In Glen Seileach, about two miles further to the south-west, the schists are pierced by a small boss of pink granite, which thus lies midway between the granite masses of Meall a Chaoruinn and Ballachulish. This rock, which is very much weathered, appears to be identical in composition with that of Meall a Chaoruinn. It has been examined by MR. TEALL, who thus describes it:

"[6562]. Pink in colour, and medium-grained, with earthy pale-green decomposition products, after a ferro-magnesian mineral. Under the microscope it is too much altered for satisfactory determination. Idiomorphic plagioclase (highly altered), very abundant, interstitial quartz, chlorite, secondary white mica, &c.—altered biotite-granite."

A considerable number of lamprophyre dykes and sills traverse the black schist and limestone between the top of the Bidean Bad na h'Iolaire and the shoulder of Sgor Chalum. In some places they are so numerous that as many as 27 have been mapped in a single mile of section in the Coire a Mhuilinn. As a rule, they are comparatively narrow, and cannot be traced far. Their general trend is towards E. 30°–40° N. One large example has been traced from the Kiachnish Water to Blarnacdrynie, a distance of a mile and a half.

Camptonite dykes and sills, which are varieties of the lamprophyres, are closely associated with these. They are found chiefly on the south side of the "Beiders," and on the shoulder of Sgor Chalum. The course of some of these can be traced for more than a mile, and their direction varies from E. 30° N. to E. 45° N., with a breadth of from 10 to 20 feet. A specimen collected to the south of Blar nan Cleireach is described by MR. TEALL as follows:

"[6559]. Dark, almost black medium-grained rock. Under the microscope acicular prisms of brown hornblende and plates of greenish-brown biotite, in a matrix of felspar, which is in part, if not wholly, plagioclase; apatite fairly abundant as an accessory; iron-ores very scarce. The felspar of the matrix occurs in large irregular individuals in which the ferro-magnesian minerals occur as inclusions, thus giving the rock a marked micro-poikilitic structure—diorite (camptonite)."

Dykes of porphyrite are less common than those of lamprophyre and camptonite. Their general direction is N. 45° E. In two instances they have been observed to cut lamprophyre dykes. Above the old military road at the Allt Riasgaig, a dark green dyke cuts the black schist and limestone. Embedded in the base are large white porphyritic crystals of felspar, often measuring a quarter of an inch in length, and giving the rock a striking appearance. An examination of this rock by MR. TEALL showed:—

"[6560]. Phenocrysts of more or less turbid plagioclase and altered biotite in a micro- or crypto-crystalline matrix; carbonates fairly abundant; they form pseudomorphs after phenocrysts of some ferro-magnesian mineral, probably augite. The rock is a porphyrite."

MR. GRANT-WILSON'S field-work last year has afforded still more direct evidence as to the exact position of the powerful fault which runs along the line of the Great Glen. Below Torcastle the river Lochy runs over a succession of rocky cascades, caused by bands of silvery mica-schist which belong to the series of rocks on the east side of the dislocation. At a distance of 320 yards to the north-west of this river-section gneissose flagstones are seen above the public road, so that the fault must pass between these two points. In the Moyburn, at the road-bridge, and for some distance up stream, the flagstones are so broken up, twisted, and veined with calcite as to be hardly recognisable. From their shattered condition it may be inferred that if this is not its actual position, the line of fracture cannot lie far off.

District of
Loch Eil and
Fort William.
(Mr. Grant-
Wilson.)

From Oban as a centre, MR. SYMES has continued his field-work, in the course of which he has had occasion to map some further small portion of the Argyllshire schists. He finds these rocks well developed about Kilmelfort. On the shore there they consist of phyllites and mica-schists, which, further to the east, are replaced by one thick band of limestone, followed by thin siliceous schists, then by epidote-chloritic biotite-schists, and lastly by siliceous schists, with occasional thick quartzites. The whole section shows a steady dip to the east; but little crumpling or repetition of the beds has been detected. The one zone of limestone which may be about 30 feet thick, but is composed of numerous beds, is not repeated as far as the survey has yet advanced. Throughout the section numerous intrusions of epidiorite were noticed in all the beds. The eruptive rock shows considerable variation, but for the most part it is of the usual dark-green hornblendic type, both compact and schistose, and very decomposed. At the waterfall on the Gleann Mor River, N.E. of Kilmelfort, bedded epidiorites occur unlike any others in the district. They are light grey in colour, and have needle-shaped crystals of felspar, as well as milk-white specks of felspar and crystals of iron pyrites in a very compact light grey matrix. These rocks occur in thick beds without any shearing, whereas the hornblendic epidiorites nearly always show signs of schistosity. The section at Kilmelfort presents a remarkable resemblance to that at Campbelltown in Kintyre, the succession of the beds being the same; but the beds at Campbelltown are much folded and form an anticline, while those at Kilmelfort have a steady dip to the east. If this inclination can be taken to indicate the general succession of strata the Kilmelfort beds would appear to lie on a much higher horizon than the black slates and associated limestone which occur at Easdale, Kerrera Island, and as far north in this district as Loch Creran.

Oban
District.
(Mr. Symes.)

For economic purposes the limestones at Kilmelfort are valuable for their marked binding properties, but they can hardly compete in a financial point of view with the richer limestones of the Carboniferous and other formations which can be brought to these coasts by sea.

In the Balvicar and other quarries about Easdale numerous

Oban
District.
(Mr. Symes.)

bands of limestone have been noted among the slates and sometimes also nodules of limestone. The slates in the Balvicar quarry are classed as blue and black; the former include large cubes of iron pyrites which are not detrimental to their sale. Both blue and black are of about the same general value in the market.

(Director-
General.)

Slates were once worked at Ardentallan, on the north side of Loch Feochan, but the quarrying of them had to be abandoned owing to local encroachment of the sea.

"Good sections to illustrate the relations between cleavage and bedding are to be seen along the shores of Seil Island. Thus, on the bend just east of Easdale school-house, the Dalradian rocks, inclined at 74° to E.S.E., consist of black slates or phyllites with intercalated beds of limestone. The slates are traversed by a cleavage which dips in the same direction at 50° . They are also finely frilled or puckered, and the cleavage-planes are covered with a silvery sericitic surface. Here foliation has taken place along the planes of cleavage. The limestones are earthy, shaly, and compact, and, like the slates, are full of cubes of pyrites.

"A few yards to the south of the part of the beach where these observations were made the strata rise in the opposite direction, but the cleavage still continues towards S.E., though with less regularity, and its planes are occasionally curved. The slates vary here not only in the direction but also in the amount of their inclination, the dip being sometimes as low as 15° and changing in a few yards to verticality."*

A large mass of diorite has been mapped east of Balvicar; the exposure extends S.W. for about two miles, its greatest breadth being about half-a-mile. Beds of dolomite with a large percentage of iron occur in it along cleavage-planes.

Island of
Jura. (Mr.
Wilkinson.)

The survey of Jura by MR. WILKINSON, during the past year, has not disclosed any new facts of importance in the geology of the island. The quartzites along their south-eastern boundary have been found sometimes to contain so much dark material, like that of the adjacent graphite schists, as to take a dark blue or black tint throughout the quartzite area. The beds are often gritty and pebbly, and along their eastern margin they appear to have been subjected to much movement. In a north-westerly direction across their strike they become more massive, and vary from fine to coarse conglomerates. The pebbles in these strata are quartz and quartzite, and a few of jasper were noticed. The more massive beds appear to be separated by occasional bands of cleaved quartzose shale, and dip steadily in a south-easterly direction at angles of from 30° to 40° . So even and uniform is their inclination that at some little distance no sign can be detected that the beds are repeated by folding. Anyone sailing round the coast, particularly on the north-western side of the island, cannot but be struck with this apparent persistent uniformity of dip. On closer examination, however,

* Notes by the Director-General made during an inspection of MR. SYMES' ground in the summer of 1898.

ample evidence is found that the strata have been repeated by a system of V-shaped folds. By this structure an appearance of enormous thickness has been given to this formation, which is probably entirely deceptive. So far no annelid tubes have been discovered in the area surveyed. The Director-General, however, found some on the west side of the island in the district over which the mapping has not yet extended.

Like the quartzites, the slates and schists of Jura exactly resemble those of the east coast of Islay, of which they are doubtless a prolongation. They probably represent the calc-sericite schists and quartzose grits of the Ardrishaig series of the mainland. Occupying a band or strip of land about two miles wide on the south-east shores of the island, they extend in a north-easterly direction along the coast as far north as the field-work has yet reached. They appear and disappear with the folds of the quartzite. Where the latter rock comes in contact with the schists it is exceedingly difficult, if not impossible, to separate the sheared quartzite from the quartz-schists of the schist series. In the quartzite area between Lowlandman's Bay and Tarbert several inlying areas of slates and graphitic schist have been met with. At Tarbert Bay, where the slates have been extensively quarried a good rough slate has been obtained, but owing to the frequent occurrence of gritty bands, so large a proportion of the rock is useless, that quarrying does not repay the cost of labour and carriage. The same remark also applies to the quarries which were opened at Inverlussa, but which have been closed for some time. The same double set of planes of movement can be traced in the schists and slates which has been noticed in the cleaved beds in the quartzite. A good example of the structure may be seen a little south of the Forest Lodge. In this group a few bands of dolomitic limestone have been observed, which generally weather with a characteristic honeycombed surface.

Between Ardfin and Ardmenish the group of schists includes intercalated sills of epidiorite. These eruptive rocks occur in massive sheets, and form dark jagged ridges along the coastline and for some little distance inland. They occur in exactly the same manner as those of Islay. The centre of each sill is generally a coarsely porphyritic rock, which would make a handsome ornamental stone if polished, as it contains large crystals of a pale flesh-coloured felspar scattered through a mottled greenish matrix. Towards the edges, the texture of the rock becomes much finer and closer, more schistose, and generally of a darker green colour. Although the ridges formed by these rocks are so numerous as to convey the impression that many sheets of igneous material have been injected into the sediments, it is probable that the appearance is deceptive, and that in reality there are only a few sills which have been repeated over and over again by a system of plication. The axes of the folds run parallel to each other in a north-easterly and south-westerly direction. Epidiorite sills do not occur in the main mass of the quartzite.

North of Loch Tarbert the epidiorite ceases to occur in the form of sills. On the other hand, a number of fine-grained dark

Island of
Jura. (Mr.
Wilkinson.)

green dykes of that rock form well-marked features as they traverse the quartzite. They run for miles, some from east to west, others from north to south, and often cut one another at right angles. One of them near Ardlussa stretches completely across the island and runs parallel to and not far from a dyke of olivine-dolerite, both of the dykes forming prominent ribs of rock.

It is worthy of note that where these dykes of epidiorite make their appearance no sills of that material are to be seen, while at the same time the ordinary olivine-dolerite dykes of the north-west or Tertiary series become much less numerous. The age of these exceptional epidiorite dykes remains to be determined. In spite of their coincidence in direction with the later dykes of the West Highlands they are probably vastly older than these. They have not yet been studied petrographically, but they are provisionally placed with the epidiorite sills. A more minute study of their internal composition and structure may throw some light on their place in the succession of the rocks of the island.

One further variety of eruptive material may be noticed here in connection with the Dalradian rocks of Jura. It is a red porphyry which occurs as sills in the quartzite north of Loch Tarbert. Its petrographical characters remain to be investigated.

Island of Arran.

(Mr. Gunn.)

The last district to be noticed in which the field-work of 1898 included any portion of the Dalradian rocks of the Highlands is the island of Arran, where during the greater part of the working season MR. GUNN continued his survey. As is well-known, the central granite of the northern half of the island is surrounded with a nearly continuous ring of schists. MR. GUNN in mapping these rocks has found that the term mica-schists under which they have frequently been referred to, is hardly applicable to them as a whole, seeing that mica is sparingly developed in them, except in the finer grained varieties, such as appear on the shore about Imachar, Pirnmill, and Thundergay. Along these parts of the coast, however, the rocks have been more than usually plicated and contain numerous quartz-veins. Generally the rock is a moderately fine-grained schistose sandstone, including occasional bands of a fine blue slate, and also rocks of a decidedly gritty character, schistose greywacke, and conglomerate with deformed pebbles. The coarsest bands are thin, and cannot be traced far. One of them, near Penrioch, contains pebbles from two to four inches long. Near Penrioch also, several thin calcareous bands are intercalated in a dark-coloured schist. One of these bands, some four or five feet thick, was formerly quarried and burnt for lime. At the northern end of the island near the Cock, a fine-grained variety of schist was a good deal quarried for slates in the latter part of the last century.

In the lower part of the Pirnmill district, the schist forms a (Mr. Gunn.) remarkable series of ridges and hollows which run along the strike or nearly so; higher up the hillsides other marked features are apparently due to joints or faults as their direction makes an angle with the strike. Near the granite the schist is much hardened, and the finer varieties assume a bluish colour. A marked set of joints seems also to have been developed in this altered rock by the action of the granite. These joints are in some places much more prominent than the foliation planes, which are nearly obliterated.

The ring of altered schist around the granite is here and there several hundred yards in width. As the rock is less easily decomposed than the granite itself, it sometimes forms a ridge at a higher elevation than the granite immediately adjoining. This is well shown in Glen Catacol, and in Glen Easan Biorach where the hardened schist has been cut into narrow gorges by the streams.

CAMBRIAN.

Isle of Skye.

The chief field-work last year among rocks of Cambrian age consisted in the search for fossils in the quartzites and limestones of Skye, which have in recent years been mapped by MESSRS. CLOUGH and HARKER. Some portions of these limestones were formerly supposed to be altered Lias, but a more careful study of their geological relations, and the discovery in them of some of the characteristic fossils of the Durness Limestone proved them to be undoubtedly of older Palæozoic age.* The fossil collector, MR. A. MACCONOCHIE, was instructed to search the two districts in Skye where these rocks are displayed—the neighbourhood of Ord in Sleat, and the parish of Strath.

While mapping the Ord district, MR. CLOUGH recognised (Mr. Clough.) among the Cambrian rocks there developed representatives of all the zones that had been previously established in the typical ground of Sutherland and Ross-shire, from the bottom of the quartzite up to the base of the Sailmhor limestone. The limestone of Ord failed to yield any fossils even to the most diligent examination. But this want of success is not surprising when it is remembered that the corresponding lower members of the limestone series at Durness have also proved singularly barren of organic remains, only one species, *Salterella pulchella*, having been found in two thin layers near the base of the Gruidaidh group. The characteristic fossil of the Serpulite grit, *Salterella* (*Serpulites*) *Maccullochi*, appears to be of rare occurrence in that

* See *Quart. Journ. Geol. Soc.*, vol. xliv. (1888), p. 62.

(Mr. Clough.) horizon in Skye, but MR. CLOUGH detected it at the mouth of the Ord River. MR. MACCONOCHIE proved the presence of the *Olenellus*-fauna in the "Fucoid-beds" at Tokavaig and Ord. He obtained from these strata the following fossils, which have been identified by MR. PEACH:—

<i>Planolites</i> , sp.	Trilobite, sp. (not <i>Olenellus</i>).
<i>Olenellus reticulatus</i> . Peach.	<i>Hyolithes</i> , sp.
<i>Olenelloides armatus</i> . Peach.	<i>Salterella pulchella</i> . Bill.

MR. PEACH has further found that the quartzites of Sleat have yielded all the various kinds of "pipes" (*Scolithus*) that characterise the zones of the "Pipe Rock" on the mainland, viz.:—

Scolithus linearis:

- " sp. No. 1 (small pipes).
- " sp. No. 2 (common pipes).
- " sp. No. 3 (trumpet pipes) = *Arenicolites* of Salter.
- " sp. No. 4 (Serpulite Grit pipes).

The first fossils found in the Cambrian rocks of Skye were obtained in 1887 by the Director-General of the Survey and MR. H. M. CADELL from the limestone slopes of the Allt a Mhullin in Strath. A few years later the Director-General and MR. PEACH gathered some more specimens from the same locality. When the ground came to be mapped in detail, MR. CLOUGH and MR. HARKER found fossils at many other places in the same parish. Last year, as the result of a careful search of the whole district, MR. MACCONOCHIE has greatly increased the list of species from these rocks. The united collections now amount to about 200 specimens, which have been studied by MR. PEACH, who reports regarding them as follows:—

Cambrian
Fossils of
Skye.
(Mr. Peach.)

"I have now made a study of these fossils in order to compare them with those obtained from Durness, and to see to which of the various groups of the Durness limestone they belong. It will be remembered that in the Durness District, as shown on Sheet 114 of the 1-inch map, and in the Report of the Work of the Survey,* the limestone was subdivided into the following groups, arranged in descending order:—

Durness Limestone	{ g. Durine.
	{ f. Croisphuil.
	{ e. Balnakiell.
	{ d. Sangomhor.
	{ c. Sailmhor.
	{ b. Eilean Dubh.
	{ a. Gruidaidh.

The following list shows the fossils obtained from the limestone of Strath, Skye, and the letters attached to the species correspond to those in the table just given, and denote the

* *Quart. Journ. Geol. Soc.*, vol. xlv. (1888), p. 403.

stratigraphical zone or zones in which the fossils occur in Cambrian Durness:—

Cambrian
Fossils of
Skye.
(Mr. Peach.)

<i>Archæoscyphia minganensis</i> , Bill. (e.)	<i>Murchisonia gracilis</i> , Hall (e. & f.)
<i>Calathium</i> , sp. (e.)	" (<i>Eunema</i>) <i>pagoda</i> , Salt.
Sponge rods (f.)	(e. & f.)
Sponge (e. & f.)	<i>Ophileta complanata</i> , Vanux.
<i>Planolites</i> , sp. (e. & f.)	<i>Oriostoma</i> (<i>Pleurotomaria</i>) <i>Calphurnia</i> , Bill. (e. & f.)
<i>Solenopleura</i> , sp.	" sp. (e.)
<i>Orthisina festinata</i> , Bill. (f.)	" operculum of (e.)
" <i>striatula</i> , Emm. (e.)	<i>Pleurotomaria calcifera</i> , Bill. (e. & f.)
<i>Orthis</i> , sp.	" sp. (e.)
<i>Euchasma blumenbachia</i> , Bill. (e. & f.)	<i>Endoceras</i> , sp. (f.)
<i>Holopea Ophelia</i> , Bill. (e.)	" (<i>Piloceras</i>) <i>invaginat</i> um,
<i>Maclurea crenulata</i> , Bill. (e. & f.)	Salt. (e. & f.)
" " operculum of ? (e. & f.)	" { " } sp. No. 1 (e. & f.)
" <i>Emmonsii</i> , Bill.	" { " } " " 2 (e.)
" <i>Oceana</i> , Bill. (e. & f.)	" { " } " " 3 (e.)
" <i>Peachi</i> , Salt. (e. & f.)	<i>Orthoceras durinum</i> , Blake (e. & f.)
" " operculum of ? (f.)	" <i>mendax</i> , Salt. (e. & f.)
" operculum sp. No. 2 (e. & f.)	" <i>pertinens</i> , Blake (e. & f.)
" " " " 3 (f.)	" sp. (f.)
" " " " 4 (e. & f.)	<i>Trocholites</i> , sp. (f.)
" " " " 5 (f.)	
<i>Murchisonia Adelina</i> , Bill.	

"A glance at this list is sufficient to show that the limestones from which the fossils were obtained represent the Balnakiel and Croisphuil groups of Durness. Several of the species here indicated are found also in Newfoundland, where they occur in strata, all of which, according to Billings, underlie those of Cow Head, which yield *Phyllograptus typus*, four species of *Tetragraptus*, *Callograptus elegans*, and several early forms of trilobite—an assemblage that clearly points to an Arenig horizon. Accepting, as there seems good reason to do, the classification by Billings of the Newfoundland rocks, the fossils here tabulated appear to be of Middle or Upper Cambrian Age."*

Wicklow and Wexford.

In the southward progress of the revision of the Silurian districts of Ireland, the field-work has now been extended across the counties of Wicklow and Wexford by MESSRS EGAN and MCHENRY. In that region, as has long been known, certain rocks occur which have been regarded as probably older than the undoubted Silurian formations, and which have therefore been assigned to the Cambrian system. This reference, however, has been based rather on lithological than on palæontological grounds. The rocks which in the south-east of Ireland have been named Cambrian, have been compared with the typical Cambrian rocks of Wales as regards their mineral composition and aspect. But

* See *Geological Survey of Canada*, "Palæozoic Fossils" (Billings), vol. i. (1861-65), pp. 336-376.

(Messrs.
Egan and
McHenry.)

they have proved singularly barren of organic remains. Some layers of red and grey shale in Wicklow and the south of Wexford many years ago yielded certain forms which received the name of *Oldhamia*, but of which the organic nature has been disputed, and even when admitted to represent organisms, considerable difference of opinion has arisen as to their grade. These forms were at all events not found in the true Cambrian rocks of Wales, so that they could afford no assistance in determining the stratigraphical position of the rocks which contain them.

It was felt, therefore, that in the revision of the older rocks of the south-east of Ireland, an effort should be made to obtain if possible more palæontological evidence as to the stratigraphical relation of the *Oldhamia*-bearing strata, and at the same time to subject their tectonic structure to the more rigid kind of examination which the progress of research and the use of maps on a large scale have now made possible and desirable. Accordingly the Fossil Collector, MR. CLARK, was instructed to search diligently for further fossil evidence, while MESSRS. EGAN and McHENRY, besides also examining the rocks for organic remains, made a careful study of the general structure of the ground. The result of these combined researches has been so far successful as to show that the *Oldhamia*-bearing strata probably form the oldest members of the Palæozoic series of the east of Ireland, but no palæontological evidence has been obtained to prove their Cambrian age. In the series of slates, however, which come next to and probably overlies these strata, a number of fossils have been found which appear to be undoubtedly referable to Arenig forms. If the ground were now to be mapped for the first time it is doubtful whether we should feel justified, on the ground merely of lithological characters and in the absence of reliable palæontological proof, in grouping any portion of the Palæozoic rocks of the south-east of Ireland in the Cambrian system. Probably the purple shales and quartzites which were long ago called Cambrian would be regarded as merely a subordinate part of the Lower Silurian formation into which they conformably pass, and some of the fossils of which they contain. But as these strata have for so many years been known as Cambrian, and as it cannot be definitely proved that they are not, they are retained by the Geological Survey in the position which they have held for so long a time. As they are so closely linked with the Lower Silurian rocks of the district in which they occur, the account of recent investigation regarding them is given in the next section of this *Summary*.

SILURIAN.

Wicklow and Wexford.

(Messrs.
Egan,
McHenry,
and Clark.)

In beginning their field work last season MESSRS. EGAN and McHENRY instituted an exhaustive search within the Cambrian

and Silurian areas of the County Wicklow and the northern parts of Wexford. They succeeded in finding fossils in many new places, and have thus provided a broader and more reliable basis for working out the structure and stratigraphy of this complicated region. The oldest strata, to which we propose to continue to apply the term Cambrian, consist of massive quartzites and red and purple shales. It is these shales that have long been known to yield *Oldhamia*. The more recent researches of the Geological Survey have brought to light numerous branching rod-like stems both in the quartzite series and in the ribband slates that come next to it. These were abundant in the rocks which have long been distinguished as "Cambrian" at Sugar Loaf Mountain, south of Bray, in Bray Head railway-cutting, and near Newcastle. Of the specimens from Bray Head (*Oldhamia*-beds), PROFESSOR LAPWORTH remarked that they are "undoubtedly of organic origin." MR. NEWTON found among the specimens from Bray Point railway-cutting, markings that may have been made by annelides; in those from Little Sugar Loaf Mountain, slender rods (*Nematolites*?) and other markings, resembling graptolites, but possibly not organic; in those from Greystones, other small rods, markings like burrows, and some which might possibly be graptolites.

(Messrs.
Egan,
McHenry,
and Clark.)

It thus appears that in the quartzite series, though it has been assigned to the Cambrian system, not a single distinctively Cambrian fossil has yet been detected, even after a prolonged and careful scrutiny.

The next stratigraphical group affords much more satisfactory palæontological evidence as to its age, which is now definitely ascertained to be that of the Arenig division of the Lower Silurian formations. It consists of an important and persistent set of slates or shales which has been named the "Ribband Series." It is on the whole sharply marked off from the quartzite series. Sometimes the two are separated by a line of fault; in other places they have been much crushed together, so that it becomes difficult to draw a definite line between them. There is no evidence that they are separated from each other by any stratigraphical break. The Ribband Series received its name from the earlier observers, on account of the regularly striped alternations of darker and paler layers in the more argillaceous portions. Its prevailing colour is grey, but buff, red, and purple tints sometimes predominate. It has been traced by MESSRS. EGAN and MCHENRY over wide tracts of Wicklow and Wexford, being clearly distinguishable by its lithological character from the quartzite series on the one hand, and from the Llandeilo and Bala rocks on the other. Though on the whole barren of organic remains, it has furnished recognisable Arenig fossils at Rock Little, south of Arklow; at Breanoge Head, south of Courtown, and at Kiltrea, four miles west of Enniscorthy.

(Messrs.
Egan,
McHenry,
and Clark.)

The following fossils from the Ribband Series have been determined by MR. NEWTON and MR. PEACH :—

Oldhamia radiata (?) (2 miles N.E. of Arklow).
Bryograptus Kjerulfi or *Callavei*.
Dicellograptus.
Dichograptus (?).
Didymograptus patulus or *latus*.
Phyllograptus (?).
Tetragraptus (?).
Caryocaris Wrighti.
Acrothele (?).
Obolus.
 Burrows, tracks, slender rods, &c.

The older rocks of the south-east of Ireland have undergone the same kind of crushing and deformation which has been traced through the similar districts further north. Besides abundant plication and crumpling, the Ribband Series often presents its grit bands in a curiously broken-up condition, portions of grit having been pushed into the argillaceous strata, so as to produce a brecciated appearance, deceptively like that of conglomerate; indeed some of these crush-breccias have actually been described as conglomerates.

Next to the Ribband Series there are occasionally found certain black slates, which have yielded graptolites of undoubtedly Llandeilo age. These slates, however, only make their appearance here and there, and do not seem to cover any large space of surface. They may be seen on the shore to the north of Courtown, where they come up again and again together with the Bala limestone. From these black shales, as exposed in the shore north of Courtown, MR. CLARK has collected *Cænograptus gracilis*, *C. pertenuis*, *Leptograptus flaccidus*, *Diplograptus mucronatus*, *Dicellograptus*, *Dicranograptus Nicholsoni*, *D. ramosus*, *D. zic-zac*, and *Climacograptus perexcavatus*—an assemblage of organisms characteristic of the Glenkiln (Upper Llandeilo) sub-division of the Moffat shales in the Lower Silurian series of the South of Scotland. He has also obtained a number of graptolites from the railway-cutting near Rathdrum, where the black shales are to be seen.

Limestones belonging to the Bala subdivision of the Silurian system have long been known to occur in Wicklow and Wexford, and are shown upon the published maps. They have yielded an abundant and characteristic Bala fauna. No evidence of Upper Silurian strata has been met with in Wicklow or Wexford.

In the course of the revision of the sedimentary rocks attention has been paid to the igneous rocks which form so conspicuous a feature in the geology of the south-east of Ireland. According to the published maps two bands of these rocks traverse the region. One band begins a little south of Wicklow and stretches south-westward beyond Croghan Kinshela; the other and more important belt, starting from Arklow Head, runs for nearly 80 miles across Wexford and Waterford to the southern coast near Dungarvan. These long interrupted strips of igneous material have been represented on the published maps of the

Geological Survey as consisting partly of intrusive sheets of both acid and basic material, and partly of intercalated sheets of acid lavas and of tuffs ("felspathic ash" and "greenstone ash"). As these maps were published from 40 to 50 years ago, and as petrography has made great progress in this long interval, it was only to be looked for that some changes would be required both in the nomenclature and in the mapping of the igneous rocks. Some progress has been made in this revision, though not enough to warrant any full statement of the alterations which are now seen to be required. Enough of ground, however, has been re-examined to confirm the suspicion aroused some years ago when the DIRECTOR GENERAL and DR. HATCH studied the sections laid bare in the Aughrim Valley above Wooden Bridge that much of the so-called "greenstone ash" was not really of fragmentary or pyroclastic origin, but consisted of dykes and sills of acid, intermediate, or basic material which had acquired a laminar structure as the result of severe compression and deformation. As far as the revision has advanced none of the "ashes" have proved to be tuffs at all. Every example met with throughout County Wicklow has been found to be only a crushed variety of some felsite or other eruptive rock, or occasionally felspathic grits. Some of these "greenstone ashes" are bands of hornblende-schist representing what was once basic intrusive material.

The sheets of rock delineated on the map as long bands of interbedded lava, so far as they have yet been studied, have furnished no evidence of contemporaneous outflow. But on the contrary numerous proofs have been met with of actual intrusion. It is too soon to decide that no true lavas occur in the more northerly of the two bands of igneous material, but no satisfactory proofs of their presence have yet been encountered. It would certainly seem that a very large proportion of the "felstones," "quartziferous porphyries," and "greenstones" are really intrusive bosses and sills.

That true volcanic rocks occur in the southern band, however, is beyond doubt, though there may be some difficulty in fixing the stratigraphical limits of the volcanic activity. Some of the best sections of these rocks have been laid bare by the sea on the coast north of Courtown in County Wexford. There some fine cliffs of coarse agglomerate and fine bedded tuffs form part of a long succession of sea-precipices in which the extraordinary complication of the geological structure of this part of Ireland is well displayed. The relations of the volcanic rocks to the ordinary sedimentary strata are often much obscured by crushing and faulting. That the tuffs are later than the Llandeilo series is shown by the occurrence of pieces of the characteristic black shales in them. That they are also later than some part of the Bala group is indicated by their including pieces of the fossiliferous Bala limestone. A little north of Duffcarrick Rocks a bed of conglomerate dips away from the Bala limestone, of which it contains abundant fragments. The conglomerate passes upwards into fine tuffs, followed again by the Bala limestone and shales

(Messrs.
Egan,
McHenry,
and Clark).

(Messrs.
Egan,
McHenry,
and Clark.)

and by more tuffs. This complicated section has not yet been thoroughly unravelled, but it seems to indicate that volcanic discharges took place during a part of the Bala period, accompanied perhaps by local disturbance and consequent unconformability.

The igneous rocks are now being studied petrographically by MR. H. J. SEYMOUR, and his determinations will greatly aid the colouring of the revised edition of the maps. An account of his researches among these rocks will be given in a subsequent *Summary of Progress*.

Central and Southern Ireland.

The revision of the Silurian rocks of Ireland was last year carried by MR. KILROE through the counties of Tipperary, Limerick, Cork, Kilkenny, and Waterford. In portions of the ground he was preceded by MR. CLARK, who searched the rocks for paleontological material to aid in determining their stratigraphical position. MR. KILROE, throughout the area examined, has found the strata to consist for the most part of dark grey and blue mudstones, with intercalated bands of dark grey, blue, and greenish grits. They usually dip at a high angle, and frequently show contortion and folding; so that beds and groups of beds are probably repeated. Cleavage is more or less perceptible throughout the several inliers, and is very fully developed in the rocks of the more southerly areas. The cleavage faces in certain places show a sericitic glaze.

Keeper Hill
District.
(Mr. Kilroe.)

The rocks of the Keeper Hill district, which are the continuation southward of those which form the Devil's Bit Hills, are chiefly of Llandovery age, though some representing a higher horizon also occur, as is the case further north. A wide zone stretching south-westward from Upper Church by Holyford has yielded an abundance of fossils at various places. The specimens named by MR. NEWTON include *Monograptus priodon* var. *Flemingii*, *M. colonus*, *M. intermedius* (?), *M. spiralis* (?), *Cyrtograptus hamatus*, *C. Carruthersi*, *Athyris* or *Glassia*, Crinoids.

As *Monograptus colonus* and *M. intermedius* are characteristic of Wenlock and Ludlow rocks, *Cyrtograptus* of Wenlock, and *Monograptus priodon* of Wenlock and Tarannon, it would seem that rocks as young as Wenlock exist in this zone. The graptolites almost universally occur in thin flaggy seams, and layers of fissile grit, which weather brown and display flattened carbonaceous markings on their bedding-planes. These peculiar seams seldom make their appearance in the grits and mudstones outside the fossiliferous zone above referred to, and those bearing fossils are of still rarer occurrence. Accordingly fossil localities are sparingly distributed over the large area extending westward from the edge of Sheet 144 to the Old Red Sandstone boundary. At the northern margin of the same Sheet, due south of Keeper Hill, fossil-bearing strata were met with, similar to those near

Holyford (Sheet 145); an arrangement which may possibly indicate that a synclinal trough of Wenlock rocks exists there. Keeper Hill District.
(Mr. Kilroe.)

An outcrop of limestone, the only one met with in the entire Devil's Bit and Keeper Hill region, was observed in the Clare River bed, near the Old Red Sandstone boundary, south of Castle Waller (Sheet 144). The outcrop, which probably coincides with the summit of a sharp anticline, may be one of Bala rocks, though unfortunately no fossils were found to establish the horizon of the strata.

The rocks in the southern part of the Galtymore area are so highly cleaved that if fossils originally existed in them they must now with difficulty be obtainable. Some, however, have been found by MR. CLARK in the disused slate quarry near Darragh Bridge (Sheet 165). In the northern portion of the district numerous specimens of graptolites were found in the townland of Ballynamuddagh, on the north flank of Temple Hill (Sheet 165); and in Lyre (Sheet 154) along the stream which forms the county boundary, north of Slievecushnabinnia. All the specimens collected have been assigned by MR. NEWTON to *Monograptus riccartonensis*, and may indicate rocks of Llandovery (Gala) age.* Galtymore District.
(Mr. Kilroe.)

An interesting circumstance which tends to establish the correlation of these rocks with the Upper Silurian series of southern Scotland, is the occurrence in them of a fossil which bears a close resemblance to, if not identity with, *Protovirgularia* (M'Coy). Several specimens of the fossil were found at a point about 300 yards south by west of Knockauchraek Bridge, three miles east of Galbally (Sheet 154).

It is believed that all the older Palæozoic rocks under notice, in this tract and in the narrow strips on the north flank of Slievenamuck, are of Upper Silurian age, no evidence, lithological or otherwise, having been noticed for the existence of Lower Silurian rocks in either area.

The area of Slievenaman, which lies to the north of Carrick-on-Suir, contains a preponderance of slates, which, with the grits that accompany them, are identical in character with those of the Mitchelstown tract; where, on the other hand, grits predominate. Several slate quarries have been worked in the region due north of Carrick (Sheet 167) and south of Windgap (Sheet 156); and slates are still obtained and manufactured at the Victoria and Ormonde Quarries in that region. From the prevalence and perfection of the cleavage, which most usually crosses the bedding, it might appear unlikely that fossils should be found in the tract; nevertheless some organic forms have been discovered, both at the disused quarries north and east of Carrigadoon Hill, and at the Victoria Quarries beside the Lingaun River, due north of Tinnakilly. The specimens that lie upon the cleavage faces consist of various branching fucoids. Slievenaman District.
(Mr. Kilroe.)

* It should be noted, however, that in the South of Scotland *Monograptus riccartonensis* occurs both in the Gala group (Tarannon) and in the Wenlock rocks of Riccarton, from which it takes its specific name, and that it is most common in the latter strata.

Slievenaman
District.
(Mr. Kilroe.)

Occasionally they lie across lines which mark the original bedding of the mudstone. Graptolite-like impressions were also found which show a serrated edge on one side, the other side being plain like the stem of a single graptolite. The impressions are all much flattened, broadened, and lengthened, sometimes waved and distorted. Mr. Newton says of them: "The specimens are interesting, as showing what cleavage may do, but they are a puzzle. The most perfect of them look like graptolites, and may possibly be the much altered remains of such organisms; but other examples suggest that they are altogether due to cleavage and are not organic." These specimens were also seen by Prof. Lapworth, who formed a similar opinion in regard to them. It is difficult to conceive how such striking impressions could result, with more or less uniformity of shape and outline, from the mere mechanical rearrangement of particles in a homogeneous rock. They are sufficiently rare to accord with the supposition that they represent linear fossils caught perhaps along the junctions of cleavage- and bedding-planes. They are numerous enough, however, to have attracted the attention of Mr. Hughes, the well-informed manager of the Victoria Quarries, who has made a considerable collection of them. Specimens were presented to the Survey many years ago by Mr. Budd, of Waterford, and were placed in the Museum as *Graptolithus Hisingeri* by the late W. H. Baily.

Glenpatrick
and Portlaw
District.
(Mr. Kilroe.)

Immediately south of Carrick-on-Suir, the district of Glenpatrick and Portlaw displays dark grey slate alternating with important bands of grit. The latter are usually ferruginous, weather brown, and are barren of organic remains. The slate, which is well exposed in Glenpatrick, was formerly extensively quarried there, at a point seven miles west by south of Carrick-on-Suir. It was found by the Survey Collector, Mr. Clark, to contain impressions similar to those found in the slate north of Carrick. Indistinct organic forms were also found in the slate at Clonea and near Rathgormuck.

The fucoid remains and graptolite-like impressions here referred to constitute the only fossil evidence yet obtained upon which a conclusion as to the age of the Silurian rocks north and south of Carrick can be based. If the impressions were really those of single graptolites they would support the belief entertained on lithological grounds that the rocks as far south as Croughaun Hill—the southern limit of the area MR. KILROE has examined—are of Upper Silurian age. The rocks are identical in general character with those of the Mitchelstown and Keeper Hill tracts, where Upper Silurian fossils abundantly occur. No fossil evidence has been found for the introduction of any Lower Silurian colour on the maps of these tracts. Finally, the strata decidedly differ in lithological character from those containing Lower Silurian fossils at Tramore.

It may be added that the slate in all the regions now reviewed is identical in character with that of the Slieve Bernagh tract, and of Slieve Arra on the opposite side of Lough

Derg. This similarity has been pointed out by MR. KINAHAN, Glenpatrick and Portlaw District. (Mr. Kilroe.)
(*Geology of Ireland*, pp. 28 to 33).

The coarse grit and fine conglomerate bands of the Slieve Bernagh and Arra tracts have their counterparts in beds which have been represented as "ash," north of Carrick-on-Suir. The material these beds consist of is a mixture of large and small grains of quartz, with some of felsite, chert (?), and fragments of black, grey, and greenish slate, similar to specimens that have been obtained from the Silurian area of West Wicklow and East Kildare, to which reference will be made a little further on.

Since his appointment in April last, MR. HENRY J. SEYMOUR Petrography of Irish Silurian rocks. (Mr. Seymour.) has been engaged in arranging, registering, and cataloguing the collection of microscopic slides of Irish rocks in the Office of the Survey in Dublin, which now number 2,181. He has had 162 new slides prepared, chiefly of Silurian igneous rocks, and has supplied the field-surveyors with determinations of the rocks for the guidance of the mapping. The specimens which he has studied and reported on were collected mainly from three districts—near Slane in Co. Meath, in Co. Cavan, and in the counties of Wicklow and Wexford.

Petrographically, the specimens examined from the Slane area are divisible into volcanic tuffs or breccias and intrusive igneous rocks. The first are of medium coarseness, and the rock-fragments composing them are mainly andesites. This material is usually finely crystalline in texture, and is frequently associated with lapilli of a scoriaceous glass, no doubt of similar chemical composition. When, as is frequently the case, fragments of both these varieties occur in the same rock-specimen, it appears in section remarkably similar to the volcanic tuff of Hyssington, Shropshire. Felsitic inclusions are not uncommon, and these often exhibit perlitic structure (I. 1,624). The ejected plagioclases are mostly andesine. The occurrence of rolled fragments, and, in one case, of fossils, points to the deposition of these clastic materials in water, together with the ordinary fragmental rocks of this area. One of the specimens examined contains anatase. The rock in which this mineral occurs is much decomposed, and is made up of clear quartz grains, and a greenish material which appears to represent altered andesite. The anatase crystals, which are very numerous, occur in the quartz; they are about 0.03 mm. in size, show the characteristic crystalline forms, and are pale brownish yellow in colour.

All the tuffs have suffered from weathering, and secondary calcite and chlorite are more or less extensively developed in them. The presence of vesicular fragments affords evidence that some of the rocks have not undergone extreme compression. Certain specimens from the district, however, have been foliated by pressure. A peculiar type of silicified limestone (1,625 and 1,627) occurs near Slane, in which the silica is present in perfectly developed acicular quartz crystals.

The eruptive rocks examined are mainly altered basic varieties. They include examples of andesites, sometimes porphyritic, dolerites, and basalts with olivine; this mineral, however, being

Petrography
of Irish
Silurian
rocks. (Mr.
Seymour.)

entirely represented by pseudomorphs. Augite is the chief ferro-magnesian constituent, but hornblende and biotite also occur; the plagioclase varies from andesine to labradorite. A kersantite occurs near Craig Baron Hill, and an augite-syenite at Dunmore.

The rocks collected from Cavan (Sheet 69) have been mapped and described as felspathic ashes and tough flaky breccias. Microscopical examination shows that this determination is correct. They are mainly schistose fragmental rocks of basic composition, and usually much altered. Lumps of andesite (diabase) and basalt, sometimes of considerable size, occur in a base of finer material, now composed of chlorite, calcite, and iron ores. Sometimes the larger inclusions show evidence of crushing, but in other cases are apparently unaffected. Scattered augites and plagioclases are generally present in the ground-mass.

In the Silurian area which lies to the west of the great ridge of the Leinster granite, and is comprised in the one-inch Sheets 120 and 129, a number of outcrops of "Greenstone ash" are noted on the published maps. As in the Wicklow region already referred to, none of these "ashes" have on recent examination been found to be tufts. Specimens representative of a limited number of them were sliced and examined, and proved to be of two types, *foliated grits* and *hornblende schists*. So far as an opinion may be formed from the topographical position on the map, of the specimens collected, each type seems to occupy a distinct area, the hornblende-schist occurring only within a zone about a mile in width next the granite, while the grits appear exclusively outside that zone.

The foliated igneous rocks are of the usual type of hornblende-schists; they often contain biotite, which in some cases at least, is a product of the alteration of the hornblende. The latter has also been altered into epidote, indeed almost every slice examined contained this mineral to a greater or less extent. Sphene is often present in well developed crystals. These rocks were possibly pyroxenic varieties in their original condition. The foliated grits vary considerably in texture, and appear to mark coarser layers in the Silurian sediments. They have shared in the general crumpling which the rocks of the district have undergone, and have thus acquired a schistose structure. Under the microscope, they are seen to be mainly composed of quartz and shaly particles. Occasionally small pieces of andesitic lavas and plagioclase crystals are present in them.

Upper Silurian rocks of Central Scotland.

Lanarkshire
and Ayrshire.
(Mr. B. N.
Peach.)

Further research has been carried on among the Upper Silurian rocks of Scotland, from which so remarkable a series of organic remains was announced in the *Summary of Progress* for 1897. When making a preliminary examination of the fossils gathered during last year from the Ludlow and Downtonian rocks of Lanarkshire and Ayrshire, preparatory to distributing them among specialists for examination and description, MR. PEACH

observed two more specimens of the remains of myriapods allied to *Kampecaris* and *Archidesmus*. The form referred to in last *Summary of Progress* as being the first recorded instance of a Silurian air-breather of this class is therefore no longer unique. It has been studied by MR. PEACH during the past year, and described to the Royal Physical Society of Edinburgh under the name of *Archidesmus loganensis*. The genera *Kampecaris* (Page) and *Archidesmus* (Peach) were made to admit two species of simply constructed millipedes from the Lower Old Red Sandstone of Forfarshire, in which the body segments were all single. In virtue of this peculiarity they have been elevated by DR. SAMUEL SCUDDER into family rank under the name of the Archidesmidæ. All the new forms appear to belong to this family, and though *A. loganensis* seems to differ widely from *A. MacNicolii*—the Lower Old Red Sandstone form—it has been provisionally placed in the same genus with it.

Lanarkshire
and Ayrshire.
(Mr. B. N
Peach.)

As was announced in the last *Summary of Progress*, the fishes found in the Upper Silurian formations have been handed over to DR. TRAQUAIR, who supplies the following note on the new forms discovered during the past year:—

Silurian
fossil Fishes.
(Dr. Traquair)

“Among the additional specimens of Silurian (Downtonian) Fishes collected by MR. TAIT in the Lesmahagow district, I have found a specimen from Seggieholm which throws light on some undeterminable fragments alluded to in my notes of 1897. It is the type of a new genus and species to which I have given the name *Ateleaspis tessellata*, and although in its form it displays an affinity with the Cœlolepidæ, a new family Ateleaspidæ must be erected for its reception.

“Among the detached and isolated fish-scales and plates collected by MR. TAIT from the Downtonian rocks of the Pentland Hills, remains of *Ateleaspis tessellata*, Traq., *Birkenia elegans*, Traq., and *Lasanius problematicus*, Traq., may be recognised, but in no case has anything like an entire fish, or portion of a fish, occurred in that locality.”

Several good specimens of a new species of *Eurypterus* of the type of *E. scorpoides*, Woodw., were collected last year from the Downtonian rocks of Ayrshire and Lanarkshire. This species was doubtfully referred to MR. LAURIE's genus *Drepanopterus* in the *Summary of Progress* for 1897 (p. 85) as it is ornamented with a sculpture similar to that seen in this genus; but the more complete specimens since obtained clear up this point. The specimens have been handed to MR. LAURIE for description, together with some other new forms in the Survey Collection, found in the Upper Silurian and Lower Old Red Sandstone strata. The Downtonian rocks have also yielded several specimens of a curious chain of disc-like bodies, connected in some instances by a slender thread of the same substance as the discs, much like a string of flattened beads. As a rule these discs are represented by a rusty ochreous decomposed material, but one or two specimens show a structure suggestive of a sponge. Accordingly a collection of about 40 specimens was forwarded to DR. G. J. HINDE, who observes regarding them:—“The markings on some resemble very closely sponge spicules, and in a general way one would have little doubt in regarding them as sponges.”

Silurian
Eurypterids.
(Mr. Peach.)

“But while these spicular markings may be accepted

Silurian
Eurypterids.
(Mr. Peach.)

as indicating the sponge character of these bodies there are no definite spicular forms shown to give a clue to their relationships." "Only on the forms quoted above are spicular impressions preserved. In regard to the other specimens forming the large majority of those sent, only the outlines in formless rusty material are shown, and whilst these are very distinct, there are no traces of spicules to be found, and thus it is a difficult thing to determine whether they are related to the few forms with the spicular markings which might be provisionally placed with the sponges. I do not think there is anything very improbable about these connected lobes being sponges; the form is unusual, but there are instances where single rounded forms occur as fossil (e.g. *Phormosella ovata*, Brit. Foss. Sponges, Pal. Soc., 1887, Pl. III., Fig. 2) in much the same condition of preservation, only showing the spicules. But until one could obtain further evidence I should hesitate to describe them positively as sponges." Until the nature of these bodies has been more definitely ascertained they may be provisionally placed among the sponges, to which at present they appear to show most affinity.

OLD RED SANDSTONE.

Caithness.

(Mr. Pocock.)

The field-work of the Survey has been carried on during the last season in three of the great basins, in which the older portion of the Old Red Sandstone of Scotland was deposited. In the most northerly of these, that which embraces the county of Caithness, MR. POCOCK continued the mapping to which reference was made in the *Summary of Progress* for 1897. He traced the Old Red Sandstone of the conspicuous group of the Morven Hills and found it to cover the whole area between the quartzite of the Scarabin range and the detached quartzite mass of Con na Craigie, not as an outlier, which it has been supposed to be, but as a continuation of the main mass of the formation lying to the east. It lies, as is well-known, with a complete unconformability on the crystalline schists and granites of the region. Its limits, which were traced last year in the neighbourhood of Glut Lodge, have been followed eastwards for a distance of over four miles along the north side of the Dunbeath Water, after which the boundary-line swings back to the west, crosses the watershed into the Berriedale valley and runs as far as the foot of the Small Mount west of Morven. The general features of the basement-beds described in the Director-General's Memoir, (*Trans. Roy. Soc. Edin.*, vol. xxviii, 1878, p. 375, *et seq.*) have been verified in the Braemore area. The following sub-divisions in descending order have been mapped:—

2. Morven conglomerate, consisting of unstratified conglomerate or breccia passing up into stratified pebble-beds; 450 feet to the top of Morven.

1. Braemore group, consisting of red and grey flagstones, red sandstones and shales passing up into arkoses and pebbly grits with coarse breccias; locally 900 feet.

The lowest beds of the series are well exposed in the river (Mr. Pocock.) section near Braemore Lodge. No basal breccia is seen at this point, the lowest beds visible being red flaggy sandstones with intercalated arkoses mainly composed of pink orthoclase derived from the orthoclase-gneiss which has been described in the account of the crystalline schists of this area. Not far from the base, beds of dark grey calcareous flagstone, similar to the flagstones of Eastern Caithness, have yielded fossils regarded by MR. PEACH as plant-remains. These beds are only traceable for a short distance, and rapidly give way to a local quartzite-breccia formed round the quartzite mass of Con na Craigie. But grey shaly flagstones of similar type and probably on the same horizon are found under the arkoses and conglomerates of Ben Bhreac on the north side of the Dunbeath Water. The occurrence of local breccias is an interesting feature in the Braemore group. They are composed almost exclusively of angular fragments of the rocks immediately underlying them, contain little or no matrix, and occur wherever a hummock of the older rocks stands up through the basal sandstones of the group. They are themselves covered by higher beds of red sandstone and shale. They point to a time when the waters of the northern basin of Old Red Sandstone, to which the name of "Lake Orcadie" has been given, extended in a long bay full of rocky islets from the region of Dunbeath to where the Morven Hills now stand, while the low watershed on the north stretched eastwards as a tongue of land separating the Morven bay from another inlet in the Dunbeath valley. The disintegration of the rocks under atmospheric agencies gave rise to coarse scree, which were buried *in situ* as the waters of the lake rose above them. Subsequently, during the deposition of the higher parts of the Braemore group, the land must have sunk so as to submerge the watershed on the north side of the Berriedale valley to a depth of many hundred feet. The breccias occur at several different horizons, and as noticed in the Director-General's Memoir, change rapidly according to the nature of the underlying rock. The quartzite breccia on the col between Morven and the Small Mount proves to be a local base about 500 feet above the bottom beds of the Braemore group. The upper parts of this group form the lower slopes of the Morven range. They consist of strata coarser in grain and more pebbly than the lower parts, whilst intercalations of dark coloured grits and arkoses with pebbles of granite, gneiss, and quartz, frequently occur in them. These pebbly beds are more conspicuous on Morven than on Smean and Maiden Pap, indicating that the shore-line probably lay to the west. The Morven conglomerate forms three outliers rising into prominent crags on Morven, Smean, and Maiden Pap. It is also seen on the north side of the Berriedale water and again on the top of the hills to the east of Glut Lodge. It is made up of boulders, rounded and subangular, lying at different angles, crowded together in a sandy matrix, which here and there contains a good deal of pink orthoclase. The boulders are derived from the granites and crystalline schists of the district,

(Mr. Pocock.) and in addition a few red sandstone blocks occur. At the top of Morven and Smean the conglomerate passes up into well stratified pebble-beds, the pebbles being only one or two inches in diameter and well rounded. They consist of the same materials as those in the boulder-bed below.

The Old Red Sandstone of this district is far more disturbed than that of eastern Caithness. Inclinations as great as 50° are common among the sandstones of the Braemore group. But though the higher beds are less disturbed than the lower, no break in the succession of strata has been detected.

Ross-shire.

(Mr. Peach.) Further south, in the county of Ross, additional tracts of the same northern basin of Old Red Sandstone were mapped by MESSRS. PEACH, HORNE, and HINXMAN. MR. PEACH'S area was a comparatively small one in the district of the Black Isle, where he traced the red and yellow false-bedded sandstones which there form the uppermost member of the system. He found among their occasional bands of conglomerate and nests of pebbles, abundant detritus of the schists of the region, and also some pieces of a decomposing dark purple andesite, which may possibly indicate contemporaneous volcanic activity somewhere in this part of "Lake Orcadie."

(Mr. Horne.) The area of Old Red Sandstone in that portion of the Black Isle mapped by MR. HORNE last year forms a strip about three miles broad, extending from Fortrose on the Moray Firth westwards to the Cromarty Firth. The strata there exposed may be grouped in the following descending order:—

6. Red and yellow sandstones, false-bedded, sometimes calcareous, with occasional scattered pebbles merging into conglomeratic sandstones.

5. Conglomerate with rounded and subangular pebbles (Ordhill and Rosehaugh).

4. Red sandstones, flagstones, and shales, with a band of shales containing limestone nodules, underlain by a thick group of felspathic sandstones (arkose), red flagstones and shales.

3. Conglomerate (with subangular pebbles of crystalline schists and granite), seen at waterfall, Rosemarkie Glen.

2. Hard grey calcareous flags and shales, with thin ribs of impure limestone. Rosemarkie Glen.

1. Basal breccia. (Whinhill, north side of Rosemarkie Glen.)

In the course of his detailed work, MR. HORNE obtained evidence confirming the views held by previous observers regarding the synclinal arrangement of the Old Red Sandstone in the region of the Black Isle. This structure was long ago recognised and described by HUGH MILLER, and subsequently by the present Director General of the Survey, while the northern portion of the district was mapped by the late MR. HUGH MILLER of the Geological Survey. (Sheet 94 of the Map).

The lowest rocks are exposed in the picturesque ravine west of Rosemarkie, and on the adjacent hill-slopes. The basal breccia (No. 1) is not visible in this gorge, being thrown out by

a fault, but it occurs on the declivity to the north, between (Mr. Horne. Whinhill and Woodside. It contains sub-angular fragments of granulitic quartz-schist, biotite-gneiss, and pieces of the adjacent pink granite. The shales and flags of No. 2 are exposed on both sides of the gorge of the Rosemarkie Burn, where they are faulted against the pink granite and are themselves traversed by small faults. They dip at high angles, and have been subjected to sharp folding. The coarse conglomerate (No. 3) forms a waterfall at the head of the glen, where it is seen to overlies the grey calcareous flagstones and shales (No. 2), both being traversed by small faults. The lower portion of group No. 4, consists of a thick succession of coarse felspathic sandstones which have evidently been largely derived from the disintegration of granitic rocks. Large fragments of felspar, not much assorted by water, form the main constituent, so much so that the rock resembles in places a granitic breccia. But the derivative character of the material is made further apparent by small scattered pebbles of granite, pegmatite, and grey quartz-granulite. The strata are visible on the beach at low tide, between Fortrose and Avoch, in the crags that form the ancient shore-cliff of the same piece of coast, and in the railway-cutting east of Avoch Station. They are, however, much brecciated,—a result doubtless of the powerful fault that skirts the base of the eastern cliff of the Black Isle. These felspathic sandstones are likewise visible on the hill-slope to the east of Fortrose. In the Shaltie Burn, near Mains of Avoch, a thin band of red shales with limestone nodules, about two feet thick, is interleaved in red flags and sandstone. Near the top of this group lies the red sandstone of Arkendeith, one of the valuable building stones of the district.

Next in order comes a band of conglomerate (No. 5), which is traceable from the Ordhill south-westwards by Rosehaugh in the direction of Munlochy. Towards the north-east it seems to merge into conglomeratic sandstone; at least, it is not traceable as a separate zone north of Ordhill.

The strata that form these five sub-divisions, have a general inclination to the W.N.W. or N.W., that is away from the axis of crystalline schists which runs from Rosemarkie north-eastwards in the direction of Cromarty. Close to that axis the angle of dip is high, varying from 50° to 70° , but it decreases westwards to 40° and 25° .

These groups are surmounted by red and yellow sandstones (No. 6), occupying the centre of the syncline of Easter Ross and covering a large area in the southern portion of the Black Isle. Excellent building stone is obtained from this group, several quarries being now in active operation (Millbuie, Suddie, Tarra-dale). Recently a quarry was opened on the Rosehaugh estate which has yielded a beautiful yellow sandstone, from which the new mansion house of Rosehaugh has been built. The synclinal structure is amply proved by the evidence obtained along the southern slopes of the Millbuie Moor in the direction of the Cromarty Firth. North of Rosehaugh, these sandstones dip to

(Mr. Horne.) the N.N.W. and N.W. at angles from 10° to 12° . Westwards by Belmaduthy they dip N. and N.N.E., while about a mile to the north of Belmaduthy they dip to the N.E. at gentle angles. Again, on the western slopes of the Black Isle, near Ferintosh, these yellow sandstones have an easterly dip from 5° to 10° .

Along the south-east side of the Black Isle, several strong springs issue from these sandstones which have proved valuable sources of water-supply for Rosemarkie, Avoch, and Rosehaugh.

An interesting feature of these uppermost sandstones is the occurrence, already referred to, of pebbles of andesite or diabase-porphyrite in them. The specimens observed by MR. HORNE were from one to three inches across, and resembled the andesite-lavas associated with the Old Red Sandstone on the south side of the Moray Firth (Gollachie Mill, Gartly, Rhynie). These pebbles have not as yet been detected on lower horizons in this district.

Beaul
District.
(Mr. Horne
and Mr.
Hinxman.)

Besides the ground surveyed by him in Easter Ross, MR. HORNE also mapped a small tract of Old Red Sandstone in the district of Kiltarlity, south of the town of Beaul. In that part of the basin of Lake Orcadie, the lowest coarse tumultuous conglomerate attains a great development, as recorded by MR. WALLACE, of Inverness. Its unconformable junction with the crystalline schists is well seen in the Breakachy Burn, a tributary of the Beaul west of Beaufort Castle. The crystalline schists likewise appear, surrounded by conglomerate, in the picturesque gorge of that river south of Teanassie. Again, along the southern margin of the Old Red Sandstone, the basal conglomerate caps Meall Mor, north of Loch a Bhruthaich. Generally, it shows little or no trace of stratification, and many of the blocks are subangular. The smaller pebbles have been locally derived, being composed of grey quartzose granulites, mica-schists, and biotite-gneiss. The larger and more highly-rounded blocks, which must have been carried from a distance, consist of granite and pegmatite. In places, this conglomerate has intercalations of sandstones and flags, as in the streams in Boblanie Wood, and in Glen Convinth.

(Mr. Hinx-
man.)

In an adjoining part of the same district some additional area of the Old Red Sandstone was mapped by MR. HINXMAN, who reports the same general results as those obtained by MR. HORNE. He traced the coarse conglomerate-breccia at the base of the series in the valleys of the river Orrin and other streams flowing from the west. It is there well displayed, and presents the appearance of a coarse tumultuous aggregate of large angular, subangular, and rounded blocks, set in a hard sandy matrix with small rounded pebbles. This matrix is, however, sometimes completely absent. The great majority of the included blocks are derived from the underlying schists, those of quartz-schist predominating. There are also boulders of red granite, generally more or less foliated, pegmatite, coarse granitoid gneiss, hornblende-schist, and hornblende-rock. It is noticeable here, as at Kiltarlity, that these boulders are usually much larger and more rounded than the fragments derived from the local schistose rocks, though in the Allt Goibhre, near the unconformable

junction, the breccia contains angular masses of mica-schist six (Mr. Hinxman.) and eight feet in length.

The upper part of the conglomerate is intercalated with shaly bands, which pass upwards into a series of grey micaceous flags and shales. These are well seen at the Bridge of Orrin, where they dip S.S.W. at 15° – 25° , but rest at lower angles of 5° – 10° in the Allt Goibhre. The flaggy series is succeeded by thick-bedded red and greenish-grey micaceous sandstones, with a few pebbly bands, and seams of green and purple micaceous shale. The sandstones are often false-bedded, while the true bedding is indicated by partings and galls of red clay. Near Redcastle the beds dip N.N.E. at low angles, and further to the west seem to be almost flat. This series affords an excellent freestone, which is largely quarried in the district. The quarries at Redburn, near Beaully, have supplied building material for the Priory at Beaully and for Beaufort Castle.

An interesting feature in the mapping of the Geological Survey Loch Garve. (Mr. Peach.) in the north of Scotland has been the discovery from time to time of outliers of Old Red Sandstone, sometimes a number of miles distant from the main body of the formation. The latest outlier of this kind was found last year by MR. PEACH while engaged in surveying the crystalline schists of Ross-shire, in the district of Lochs Luichart and Garve, which have already been referred to. It stands on the hill called Craig a Chaorinn, which overlooks the south-western angle of Loch Garve. It consists of a coarse conglomerate made up of rounded and more or less angular fragments of Moine-schist, muscovite-biotite-gneiss, with a few fragments of hornblende-schist and augen-gneiss. The blocks are huddled together with little or no finer matrix. The preservation of this outlier is evidently due to a mica-trap which ascending from a dyke or sill that traverses the underlying schists, has forced its way between the pebbles and cemented them together. The conglomerate has evidently rested on a very uneven surface of the schists, for at one place the molten rock, after traversing the conglomerate, has invaded a sill of hornblende-schist and has carried with it rounded conglomerate pebbles.

Lorne.

In the Old Red Sandstone basin of Lorne some interesting (Mr. Symes.) additions have been made to our knowledge during the past year by the work of the Survey. In the *Summary of Progress* for 1897 an account was given of the discovery of *Cephalaspis*, near Oban, whereby the sandstones, shales, and volcanic rocks of Lorne were definitely proved to be of the age of the Lower Old Red Sandstone. Further investigation has resulted in the discovery, by MR. SYMES, of another locality for fossil fishes, and in the finding, by MR. PEACH, of the best specimen that has yet been obtained from this region. This ichthyolitic band occurs on the mainland shore of Kerrera Sound, about three miles south from Oban, where grey fine-grained flags are seen intercalated

(Mr. Symes.) in the conglomerate on which the andesitic lavas rest. The fine ichthyolite referred to is an excellent example of the new species, *Cephalaspis lornensis*, showing the body and fins. It is now being figured by Dr. TRAQUAIR, who in regard to the other fish-remains obtained by the collector, MR. TAIT, has been good enough to furnish the following note:—

(Dr. Traquair.)

“The additional fish-remains from Oban collected by the Geological Survey during the year 1898, though of great interest, are unfortunately not well enough preserved to justify their specific determination. Two forms new to the locality have occurred;—one is a small Acanthodian fish belonging to the genus *Mesacanthus* and closely resembling the *M. Mitchellii*, Eg., of the Forfarshire beds; the other is a small fragment of what may turn out to be a new species of *Thelodus*.”

MESSRS. PEACH and SYMES also noticed plant-remains in the same fish-bearing band, but the specimens were found by MR. KIDSTON to be too indistinct for satisfactory determination.

(Mr. Symes.) In prosecuting his survey, MR. SYMES has found that the deposit of sedimentary strata, which in the northern and western parts of the Lorne district intervenes between the base of the volcanic series and the underlying slates, reappears also in the south, where it has not hitherto been shown on published maps. About two miles N.N.E. of Kilmelfort a good section may be seen of these sediments. From under the horizontal sheets of lava the conglomerate emerges as a vertical wall, about 100 feet high, resting on vertical siliceous schists. Between the conglomerate and the bottom of the lavas there intervene about fifty feet of purplish flagstones, but without any apparent representative of the fossiliferous zone which elsewhere is found on this horizon. The blocks in the conglomerate are on the whole more angular than around Oban, and are varied in composition. Among them the following rocks were observed:—andesite, limestone, sandstone, calcareous sandstone, tuff, porphyritic epidiorite, garnet-schist, and quartzite, but no granite. Occasional thin beds of sedimentary material occur in this thick mass of coarse detritus, but they are not constant.

In the district round Oban a number of thin beds of purplish shales, sandstones, and fine conglomerate were found intercalated with the andesite sheets at different horizons. One, only a few feet thick, was traced in the Glen Lonan valley, about 500 feet above sea-level; another was met with on the road to Loch Nell, close to Baligoun, made up of thin shales, and small water-worn pebbles of quartz; while in the Feochan valley, four miles S.E. of Oban, three outcrops of shales were mapped.

On the east side of Eilean nan Caorach, which is N.W. of Easdale, the andesites are found resting on tuff close to the water edge, and below the tuff lie red, green, and purple shales, and thin conglomerate. Again, at the base of the cliff, in the amphitheatre known as Sloc ant Sisnian, about half-a-mile north of Easdale village, two small exposures of red and grey shales dipping N.W. at 20°, and traversed by numerous basalt dykes, were detected underneath the volcanic series. Similar strata appear below the andesites at Ardetallan on the north shore of

Loch Feochan, where they include hard greenish grits which were (Mr. Symes.) formerly worked extensively for building purposes. The quarry had to be abandoned because, as the surface was only 25 feet above high-water mark the excavations were flooded when they reached sea-level. This quarry, and one at Barnacarry, on the south of Loch Feochan, are the only quarries of the same material in the whole district.

The conglomerate in the Dunollie grounds at Oban contains much more matrix than the same deposit further south. It has been subjected to so much compression and dislocation that its great andesite blocks are all crushed and broken up.

In the railway cutting near Oban, and at the locality on the Sound of Kerrera already referred to, the fossiliferous band lies only about fifty feet above the black shales of the metamorphic series. The conglomerate which emerges from underneath this band is somewhat different from that of the conspicuous cliffs near Oban, inasmuch as its blocks are only about half the size, are enclosed in a less proportion of cementing material, and include a much larger percentage of quartzite fragments.

A large part of the area surveyed by MR. SYMES last year has lain among the volcanic rocks of the Lower Old Red Sandstone, which form so conspicuous a feature in the geology of the district of Lorne. He has now extended his survey to the southern margin of the volcanic area, where the lavas terminate as usual in a line of picturesque cliff crowning a talus slope that descends to the surrounding lower ground. No special petrographical distinction was observed in the characteristics of the lavas in the southern part of the region. No tuffs have yet been noticed among them.

East from Oban the observer ascends over the andesite sheets until he reaches an horizon of tuff which lies about 400 feet above the base of the lavas. Above this platform of pyroclastic material another series of lava-flows is met with which stretches for some twelve miles east of Oban. It is difficult, however, to follow the true stratigraphical succession, and to estimate the real thickness of the volcanic series, for the whole country is broken up by numerous N.N.E. faults which not impossibly repeat the beds. But assuming that the volcanic rocks about Taynuilt are higher than those to the west of them we can observe a decided petrological change in the character of the lavas that occur about two miles to the north-west of Taynuilt at Airds Park. The sheets there exposed are of a more acid type than that of the usual Lorne andesites. They weather into a purplish-red, and show a finely-banded rhyolitic structure. Not improbably they lie on the same horizon as those recorded by MR. KYNASTON from the Glen Nant Valley (*Summary of Progress for 1897*, p. 84).

Cracks filled up with hardened sandstone are frequent all through the andesitic sheets, and are in every respect similar to those which have now been observed so commonly among the lavas of the Lower Old Red Sandstone. The sandy silt has been

(Mr. Symes.) washed into fissures and cavernous hollows of the cooled lava, and where these spaces have run along the middle of a single sheet they sometimes present a deceptive resemblance to ordinary sedimentary intercalations that separate distinct flows of lava. Thus the seam of sediment eight inches thick, referred to in the *Report* for 1896 (p. 55) as intercalated between two lavas west of Connel Railway Station, has proved on subsequent examination to be only a portion of one of these sand-filled rents in the andesite.

The tuffs which cover so large an area on the north side of Loch Etive have been traced on the south side of the loch in a S.S.W. direction from the sea-level at Ach-na-cloich Railway Station to the high ground overlooking Glen Lonan where they appear to die out. Over part of this ground they form a striking feature in the landscape, for their outcrop terminates in an almost continuous vertical wall, like a great sill, which is broken in places by faults whereby portions of the cliff have been displaced.

(Director
General.)

The DIRECTOR GENERAL, during his inspection of MR. SYMES' ground last summer, made the following field-notes on the sections of tuff to be seen near Ach-na-cloich. "In the grounds south of the Railway, exposures of a pink porphyritic rock occur, which might easily be taken for a felsite or felspar-porphry. It has a dull, compact, felsitic matrix which when fresh takes a streak of steel. Through the matrix are scattered abundant pink feldspars and a smaller proportion of much decayed mica. No free quartz was detected. Most of the feldspar looks like orthoclase, but there may be some striated feldspars also. From the few exposures here, one might naturally class the rock provisionally as probably an intrusive orthoclase-porphry or somewhat altered trachyte, so far at least as its characters can be judged of in the field. It no doubt belongs to the same group as the 'crystal-tuff' observed further to the south-east by MR. KYNASTON (*Report* for 1896, p. 54)

"But a little to the west, in the railway cutting, a section is laid bare of a similar rock which unquestionably forms part of a series of tuffs, of which the true pyroclastic nature is made evident by their abundant lapilli. These tuffs present a fine-grained pinkish felsitic-looking matrix through which are abundantly scattered crystals of pink feldspar and flakes of biotite. The feldspars are sometimes striated and are generally remarkably fresh. Here and there a feldspar crystal may be seen having a dull worn outer surface as if it had undergone some attrition or solution before being enveloped in the matrix. These crystals seem to have been ejected as loose lapilli from the explosion of some feldspar-porphry. The larger lapilli are angular fragments of dull felsitic-like material. The tuffs are distinctly bedded and consist of finer and coarser detritus. During the short time spent in their examination they yielded no fragment of the ordinary andesite, nor were they found to contain layers of sandstone or shale or any appreciable admixture of ordinary non-volcanic detritus. They seem to point to volcanic explosions of a nature

quite distinct from that of the Oban lavas, when a magma of a more acid composition, like that of a trachyte or rhyolite was blown into dust. (Director General.)

"Immediately below the tuffs on the north side of the railway cutting an andesite appears of the usual dull green compact type. It includes nests and veins of shaly sandstone, the stratification of which coincides with the dip of the andesite and of the tuffs. It also contains patches of tuff which show small lapilli of highly though minutely vesicular andesite. This tuff has probably fallen into hollows and rents of the lava. It is quite different from the orthophyre-looking or trachytic tuffs above."

Thin beds of compact brick-red tuff dipping east at 15° to 30° (Mr. Symes.) are interposed between the andesite sheets near Benbeg, two miles south of Connel. In the railway cutting a mile and a half east of Oban similar tuffs were met with lying on intercalated shales and dipping east at 5° . On Eilean-nan-Caorach brick-red tuffs were found at low-water-mark lying on similar strata. These tuffs, however, appear to have no connection in age or composition with the great mass that lies to the north and south of Loch Etive. A considerable thickness of tuff has been noticed on the high ground a mile and a half to the north of Easdale village, lying on the lavas, and, like these, dipping at about 20° to N.W. On the shore of Loch Feochan, a mile west of Glenfeochan, an agglomerate has been laid bare composed entirely of fragments of andesite. On the north shore of Loch Etive, near the Manse, a similar rock is capped with a lava sheet which has cracked so much in cooling that it looks as if it were composed of subangular blocks cemented together by sedimentary material. Highly micaceous sand has during the cooling of the lava been washed abundantly into its fissures.

Some of the masses of agglomerate now referred to may possibly mark the positions of volcanic necks. But, so far as the mapping has yet gone there has been a singular absence of evidence of the orifices from which the volcanic materials were ejected.

In the *Summary of Progress* for 1897 (p. 64) reference was made to an interesting discovery by MR. WILKINSON of a volcanic mass at Glas Eilean, a small islet off the Jura shore at the southern entrance to the Sound of Islay. During the past summer the DIRECTOR GENERAL landed on this islet, and obtained confirmatory evidence that the rocks which form it belong to the same Lower Old Red Sandstone series as the lavas of Lorne. The rocks appear to consist chiefly of purplish-grey amygdaloidal andesites and decayed basalts. They show abundantly a true slaggy structure, their vesicles being commonly filled with calcite. A conspicuous feature among them links them with the volcanic series of Lorne and of the Lower Old Red Sandstone of central Scotland, viz., the abundance of veinings and irregular layers and nests of pale and red fine sandstone. Some parts of the lava have been entirely broken up into masses of slag, between which the sandy sediment has accumulated, precisely as may be seen (Director General.)

Sound of
Islay. (Director
General.)

on the coast-sections at the Red Head of Forfarshire, Turnberry Point in Ayrshire, and many sections round Oban.

The lavas of this islet occur in successive sheets, dipping towards the Sound at perhaps as much as 30° to 40° . They are separated by grassy hollows, some of which may conceal bands of tuff or ordinary sedimentary material. There can hardly be any doubt that Glas Eilean is a fragment of a volcanic series of the age of the Lower Old Red Sandstone. It lies nearly forty miles to the north of the rocks of that period in Arran and Cantyre, and fifty miles south from the volcanic masses of Oban. It not improbably marks the site of a distinct volcanic area about half way between that of Lorne and that of the Clyde.

Lorne
volcanic
series. (Mr.
Kynaston.)

During the past year Mr. KYNASTON has completed the survey of the volcanic series between the rivers Awe and Nant. Nothing exceptional has been noticed by him in the course of the mapping. The same types of rock which have been fully described by him in former *Annual Reports* continue to prevail in the ground more recently traversed. It may be mentioned, however, that he met with an excellent exposure of the nodular variety of the more acid (rhyolitic) type of the lavas near Taynult. The nodular structure is there exhibited in great perfection, some of the larger nodules measuring more than an inch in diameter.

In the *Annual Report* for 1896 reference was made to a small patch of sedimentary rocks, long ago noticed by MACCULLOCH, which occurs at the Pass of Brander, but the stratigraphical position of which was uncertain. In the *Summary of Progress* for 1897, in further allusion to these strata, it was mentioned that Mr. KYNASTON believed them to be interstratified with the Lorne andesites, and thus to be part of the Lower Old Red Sandstone. It was stated at the same time that though they had hitherto proved devoid of organic remains, their more shaly parts might prove to be fossiliferous. They were accordingly searched last year by the fossil collector, Mr. TAIT, who succeeded in obtaining a collection of plants which leaves no doubt that the strata in question are of Carboniferous age. A fuller account of them in their interesting bearing on the geological history of the West Highlands will therefore be given in the section on the Carboniferous system in later pages of the present volume (p. 129).

Granites of Ben Cruachan and Glen Etive.

(Mr. Kynas-
ton.)

In continuation of his field-work reported in the *Summary of Progress* for 1897, Mr. KYNASTON has pushed the mapping still further across the districts of Ben Cruachan and Glen Etive. He has surveyed considerable tracts of eruptive rock, and has devoted special attention to the phenomena of contact metamorphism around these tracts. The effects of the Ben Cruachan granite on the surrounding rocks were recognised by Mr. HILL in 1893, when he traced the comparatively unaltered limestones and phyllites of the Loch Awe series across the Pass of Brander

into the neighbourhood of the granite. Mr. KYNASTON having (Mr. Kynaston now mapped the ground around the granite, has supplied the following digest of the chief results of his work:—

1. *Ben Cruachan District*.—In this area MR. KYNASTON has completed the mapping of the altered rocks and diorites of Ben-a-Bhuridh and the eastern spurs of Ben Cruachan, situated to the west and north-west of Loch Awe Hotel. Reference was made in the *Summary of Progress* for 1897 (p. 86) to the diorite of Ben-a-Bhuridh, and last year further specimens of these rocks were submitted to MR. TEALL. The rock is decidedly more basic than the normal type of Ben Cruachan, and closely resembles the dioritic varieties found among the granitic intrusions of the Southern Uplands. At the quarries, about a mile north of Loch Awe Station, the rock consists of a coarse-grained, massive quartz-diorite, not unlike some of the grey varieties of Ben Cruachan and Bonawe. Under the microscope, zoned plagioclase (oligoclase-andesine), biotite, hornblende, and interstitial quartz are seen, while apatite, sphene, epidote, and iron-ores occur as accessories. Passing from here to the crags on the northern ridge of Monadh Driseag, and to the eastern and southern slopes of Ben-a-Bhuridh we find the rock becoming darker in colour, more basic, and generally rather finer-grained. A specimen from the south side of Ben-a-Bhuridh shows, under the microscope, idiomorphic plagioclase, brown hornblende, biotite, interstitial quartz and micropegmatite, the two latter constituents appearing only in very small quantity; magnetite and apatite occur as accessories. The distribution of the diorite in this area is especially worthy of notice. It distinctly forms a belt or zone varying from about $\frac{1}{8}$ to $\frac{1}{4}$ mile in breadth, along the southern boundary of a large inclusion of altered epidiorite. This inclusion constitutes a large elongated mass, which forms the whole of the highest portions of Ben-a-Bhuridh, running east and west, and then bending round in a north-easterly direction across Coire Creachan and Allt Mhoile. It is more than three miles in length, and attains a maximum breadth on Ben-a-Bhuridh of about half-a-mile. The zone of diorite, however, is only found along its southern and south-eastern boundaries; along the line of contact on its northern and north-western sides, the more *acid* type of the main mass of the Cruachan granite makes its appearance. The question naturally arises: Why should this dioritic modification of the granite occur in such close association with this included mass of epidiorite. It is certainly difficult to explain except on the supposition that an inter-action of some kind has taken place between the epidiorite and the intrusive rock, but if so, why does the granite show no modification of this kind on the opposite side of the epidiorite? Lacroix, in his valuable paper on the Granites of the Pyrenees,* has described numerous cases of basic modifications in the granite, which he attributes to endomorphic action between the

* Lacroix. "Le Granite des Pyrénées et ses phénomènes de contact."
—*Bull. des Services de la Carte géologique de la France*. No. 64. 1898.

(Mr. Kynaston.)

granite and limestone, acting within the granite magma, and he describes aureoles of endomorphosed granite (diorite, &c.) around included patches of calcareous sediment. It is perhaps possible that something of the same kind may occur here, and the peculiar zone of the Ben-a-Bhuridh diorite may be compared to the peripheral zones of hornblendic rock round included patches of limestone in the Pyrenees. It is possible that the exact conditions requisite for the assimilation of more basic material did not obtain on the northern side of the epidiorite inclusion. While mapping the northern and north-western boundary of the epidiorite, MR. KYNASTON noticed numerous strips of quartzose sediment, sometimes at the actual contact with the granite, sometimes folded in with the epidiorite, and the latter rock itself is here far less rich in hornblendic material than towards its southern margin; in fact, in many places, as at Lairig Torran, in the crags above Allt Mhoile, and in the Allt Mhoile burn, the rock shows little or no hornblende to the naked eye. It is grey and gneissose, with indications of porphyritic felspar. This, however, no doubt, merely represents a variety of the original epidiorite sill, and we know that considerable variation is an exceedingly common feature of the epidiorites of the Loch Awe and neighbouring areas. This, then, may very possibly be an explanation why no dioritic modification of the granite is found on the northern side of the Ben-a-Bhuridh inclusion. On the one side, the southern, where, until a better explanation offers itself, it may be assumed that basic material has been assimilated by the granite magma, we have an epidiorite very rich in hornblende, while on the other side a highly felspathic rock occurs with bands of quartzose sediment, which would not so readily lend themselves to any such endomorphic action. Further reference will be made in later pages to these epidiorites in connection with the contact metamorphism round the Cruachan granite.

2. *Glen Etive District.*—The mapping of the granite of the Black Mount deer-forest was continued this year from Glen Etive. At the same time a considerable area of granite and metamorphic rocks was mapped on the western side of Glen Etive, and on the higher ground and passes forming the watershed between Glen Etive and Glen Creran. In previous *Reports*, descriptions have been given of the Glen Etive type of granite from the area bounding Loch Etive and Glen Kinglass, and MR. KYNASTON'S opinion has been stated that the coarse and more acid Glen Etive rock is slightly later than that of Ben Cruachan, though belonging to the same geological period. The mapping of the Glen Etive area has fully confirmed this inference. The Glen Etive granite appears to constitute a large roughly oval-shaped mass, and this body of coarse and more acid material seems to form a huge core or plug within a slightly more basic and rather variable granite, of which the hornblende-granitite of Ben Cruachan may be taken as the type. The Cruachan type, then, forms a great, outer, encircling belt to the Glen Etive type. On passing from the former type to the latter, we notice an

abrupt change from a medium-grained rock, often rich in hornblende and plagioclase, to a very coarse and conspicuously porphyritic type of granite, in which the hornblende is greatly diminished, while quartz is frequently conspicuous. The difference between the two granites is further brought out in the slightly different types of scenery which has resulted from differences of weathering and disintegration in the two masses. (Mr. Kynaston.)

To the west of the head of Loch Etive the boundary line between the two granites runs along the eastern flanks of Ben Sguliaird and round to the north side of Airidh nan Lochan, at the head of Glen Ure. Here, however, they do not seem to be separated by a very hard-and-fast line, but a rather gradual passage may be traced from the one type to the other. The quartz of the coarse porphyritic type decreases, while the hornblende increases, and sometimes the large porphyritic feldspars of the Glen Etive type seem to pass over into the more hornblendic type. In fact, in this neighbourhood the two granites are scarcely distinguishable over a belt of perhaps twenty yards or so; while elsewhere, as a rule, a sharp line can easily be distinguished between them with the naked eye. From the head of Glen Ure the boundary-line may be followed to the upper part of Allt Bhiorain, whence it trends more to the east, keeping for some way parallel with the northern side of the burn. Thence it curves round slightly to the north-east, passes north of Creag Dubh, and crosses the river Etive close to the schoolhouse. On the eastern side of the river it is easily carried in an almost due easterly direction up Glen Ceitlein, bearing round to the south-east, up to the col between Meall Odhar and Meall nan Eun, whence it probably runs in a general southerly direction to join the boundary line, already traced, in Glen Kinglass. As far as the mapping has gone there is no contact between this granite and any sedimentary rock, nor does it contain any inclusions of such rock. It is entirely surrounded by the Cruachan type.

The coarsely porphyritic structure, which is everywhere so conspicuous at the margin, is, however, not a uniform feature. The porphyritic crystals gradually die out towards the inner portion of the mass, and thus the porphyritic structure is here merely a marginal feature. There is, in fact, a coarsely porphyritic marginal zone to the Glen Etive granite, varying from about a quarter of a mile to a mile in breadth. Within this zone lies a generally coarse, homogeneous, pinkish biotite-granite, with hornblende rather as an accessory than as a principal constituent. The rock often resembles the more acid pink variety of Ben Cruachan, and there are occasionally, as on Ben Starav, considerable variations in texture.

Specimens of the Glen Etive granite from the Glen Kinglass area, were examined under the microscope by MR. TEALL. The coarse variety of the biotite-granite from near Doire-nan-Saor was found to show zoned plagioclase, biotite, and interstitial alkali-feldspar in large plates, while quartz is comparatively scarce. Hornblende, sphene, and iron ores are accessories. The interstitial feldspar is often developed as micropertite.

(Mr. Kynaston.)

Other slices of the rock again show a good deal more quartz and sometimes rather less biotite, though on the whole only slight variation in composition is observable in this type of granite. Fine-grained varieties are found on Ben Starav, but the constituents are the same as in the coarser specimens. The alkali-felspar occasionally shows microcline structure. A fine-grained grey rock from Coire-nan-Lair, on the south side of Ben Starav, shows porphyritic or pseudo-porphyritic constituents in a finer-grained matrix. The larger constituents comprise zoned plagioclase, micropertthite, quartz, and biotite, while the ground-mass is a micro-crystalline aggregate of quartz and felspar. Small veins and bands, fine-grained, and consisting mainly of quartz and felspar, are not uncommon in certain places. Coarse pegmatitic veins are also met with about Ben Starav and Ben Trilleachan.

The porphyrite dykes and sills, however, so numerous and characteristic in the Cruachan granite, are entirely absent in the Glen Etive mass. This would seem to imply that the Glen Etive granite is of later date, or perhaps of about the same date as the porphyrite intrusions. There are nevertheless in the neighbourhood of Ben Starav a few small basic dykes, with a general N.W. and S.E. trend, of a rather peculiar rock. MR. TEALL remarks that these dykes consist of rocks of a very unusual type. A specimen from Coire-nan-Lair, on the southern side of Ben Starav, shows under the microscope green pseudomorphs after olivine, idiomorphic augite (very abundant), brown basaltic hornblende, biotite (same colour as the hornblende), felspar (scarce), magnetite, and some undetermined interstitial matter. The rock is a kind of Hornblende-Basalt. Possibly it may be connected with some of the more basic modifications of the underlying magma, which here and there may have made their way to the surface during the later dyke-forming phase. Thus, in the Kilchrenan area, one of the later sills consists, not only of the normal porphyrite, but also of a basic modification (*Summary of Progress for 1897*, p. 60) which consists of phenocrysts of brown hornblende, plagioclase, and malacolite, in a ground-mass of lath-shaped plagioclases, chlorite, and iron-ores. There are also one or two sills on Ben Duirinnis, above the Bonawe quarries, consisting of a rock allied to the camptonites, a specimen showing under the microscope large aggregates of hornblende crystals in a ground-mass of hornblende needles, felspar, and iron-ores. The small basic dykes in the Glen Etive area may possibly represent the final stage of the igneous activity of the district, after the divergent differentiation had proceeded to its final extent in the magma which constituted the source of supply of the various intrusive rocks.

The granite of the Ben Cruachan type is everywhere well-developed in the Glen Etive area outside the inner Glen Etive mass. There is not much more to be said concerning its mineralogical characters, beyond what is already known from the more typical region of Ben Cruachan itself. Occasionally it has a slightly foliated structure along its line of contact with the

Glen Etive mass, but this is not nearly so well shown as in (Mr. Kynas-Glen Kinglass (*Op. cit.*, p. 91). Sometimes the pink and more acid variety is well exposed, as along the ridge of Ben Sguliaird, where the rock is identical with that composing the upper portion of Ben Cruachan itself, and again about the summit of Meall Odhar, while sometimes, and perhaps more frequently, the more hornblendic variety predominates, and the rock, as at Bonawe, partakes rather of the character of a quartz-diorite.)

Diorites, of rather more basic character, occasionally occur as sill-like intrusions among the schists outside the granite area, and similar rocks have already been noticed near Glen Kinglass (*Op. cit.*, p. 92). A specimen from Coire Cereail, on the west side of Glen Etive, is a coarse-grained rock, almost entirely composed of hornblende. Under the microscope large individuals of hornblende are seen, which mutually interfere, together with a small quantity of turbid felspar. Apatite is more abundant and occurs in larger individuals than in the diorites of the main mass. The Glen Kinglass rocks of this type, classed rather as augite-diorites, show large individuals of pale augite partially replaced by green hornblende, biotite, and more or less idiomorphic zoned plagioclase. Occasionally, too, there is some interstitial alkali-felspar and quartz.

The later sill-like intrusions of *Porphyrite* are exceedingly numerous in the Cruachan type of granite, and in the surrounding schists throughout the Glen Etive area. They are identical in character with those already described in previous *Reports* from other areas further south, and they maintain the same general trend.

The outer boundary-line of the granite, where it comes in contact with the altered schists, is sometimes simple and well defined, but frequently, on the other hand, it is exceedingly complex, the marginal portion being inextricably mixed up with numerous broken-up strips and fragments of sedimentary material. In the neighbourhood of Beinn Fhionnlaidh, to the west of Glen Etive, a rock frequently appears, which consists of an intimate mixture of altered schist and granite, some parts presenting a profusion of small elongated fragments of schist embedded in a granitic matrix. Sometimes, too, where the granite is in contact with quartzite, numerous small fragments of quartzite are distributed freely and closely in the marginal portion of the granite. The fragments, however, are always angular and sharply defined, and show no signs of partial digestion by the granitic magma. The great number of inclusions of all sizes of altered schist in this area forms a striking feature of the Cruachan type of granite. The mode of intrusion of the granite may have partaken somewhat of the nature of a gigantic sill, the granitic paste forcing its way under pressure along the cleavage planes of the sediments, breaking them up, and flowing round the detached fragments.

In connection with the dykes and sills, mention should be made of a rather unusual type of quartz-porphyry, which occurs in the Cruachan granite at Bealach Odhar, about three miles

(Mr. Kynaston.)

east of Loch Etive head. It contains large pink feldspars, up to an inch in length, smaller white feldspars, lath-shaped hornblendes, some biotite, and small grains of quartz, in a rather compact, pinkish feldspathic matrix. Now this rock is exactly what we should expect if a portion of the magma which consolidated as the coarse Glen Etive type of granite had been intruded into a fissure to form a dyke or sill. The porphyritic minerals of the sill have such close relationships to those constituting the primary constituents of the Glen Etive granite, that the conclusion can hardly be avoided that both rocks were directly derived from the same homogeneous magma, or "sub-magma" of the general source of supply. The sill in question is very near the margin of the Glen Etive granite, (about half a mile from it,) and is perhaps an apophysis of the main mass. Close relationships may also be observed between this sill and the normal porphyrites, which are numerous in this neighbourhood, but the relationships are rather those which have already been noticed as holding between the Glen Etive and Cruachan granites. Taking these relationships and other facts into consideration, MR. KYNASTON is of opinion that the period of intrusion of the Glen Etive granite would correspond to the latter portion of the dyke- or sill-forming phase of the various intrusions. Thus the chronological order would be:—

1. Ben Cruachan *Granite*.
2. *Porphyrite* dykes and sills.
3. Glen Etive *Granite* and *Quartz-Porphyry* dykes and sills.

CONTACT METAMORPHISM AROUND THE BEN CRUACHAN GRANITE.—Reference has been made in previous pages to the alteration of the surrounding rocks which has accompanied the intrusion of some of the younger granites of the Highlands. The huge granitic mass of Ben Cruachan affords special facilities for the study of the phenomena of contact-metamorphism, for not only does it contain an enormous body of eruptive material, but the Dalradian sedimentary formation around it had undergone so little alteration before it invaded them that its effects upon them can be satisfactorily studied over a wide area. Some of MR. KYNASTON'S observations on this interesting subject have appeared in previous *Reports*, but his work last year has led him into a more extensive examination of the influence of the granite, as explained in the following digest:—

1. *Loch Awe district, Ben-a-Bhuridh, and the south-eastern end of the Pass of Brander*.—In this area certain members of the "Loch Awe Series," on being traced up to their contact with the granite are found to have undergone considerable contact-metamorphism. The degree of alteration increases towards the granite in such a manner as to leave no doubt that it has been caused by the direct action of the granitic intrusion. The sedimentary rocks here exposed may be conveniently divided into the following groups, though no hard-and-fast line can be drawn between any of them:—

- (1.) The *banded calcareous series*, of the south-east end of the Pass of Brander. These rocks are especially well

seen in the neighbourhood of the Falls of Cruachan. (Mr. Kynaston.) Occasionally good bands of pure limestone are intercalated among them.

(2.) The *black schists*, of the south and south-eastern slopes of Ben-a-Bhuridh,

(3.) *Quartzose schists, gritty beds, and quartzites*, of the eastern portion of Ben-a-Bhuridh, and Monadh-Driseag. Calcareous beds may appear in either of the last two series, and black-schists are frequently intercalated with the more quartzose beds.

A short account of the metamorphic phenomena in the neighbourhood of Bonawe, where fairly similar rocks to those of Ben-a-Bhuridh also occur, was given in the last *Summary of Progress*, and special attention was there called to the cordierite-bearing hornfels.* In the Loch Awe area a large number of specimens of altered rocks at, and at various distances from, the granite contact, was collected by MR. KYNASTON. These were submitted for microscopic examination to MR. TEALL, who has furnished the following report on the banded calcareous series, and the cordierite-bearing rocks, which occur in this area also:—

"The rocks of the '*banded calcareous series*' were evidently fine-grained sedimentary rocks, in which the relative proportions of argillaceous, arenaceous, and calcareous material were liable to repeated variations. Subsequent to their formation they must have been folded and cleaved, so that the original laminae of arenaceous and calcareous material were more or less broken up into lenticular folia. Sometimes the different types of sediment were, as it were, kneaded together without the development of any well-defined parallel structure. This, however, only applies to small portions of the specimens. Strain-slip cleavage is often recognisable in the dark bands. The contact action appears to have been subsequent to the movement, and to have destroyed to a great extent the schistosity produced by it.

(Mr. Teall on Banded Calcareous Series.)

"The rocks are now fine-grained or compact, and consist of thin alternating folia, of a dark purplish, and pale grey, greenish, or yellowish colour. The dark folia represent the more argillaceous laminae of the original sediment. They are now largely composed of a confused aggregate of micaceous and chloritic minerals, amongst which the characteristic brown mica may be observed. In one or two specimens small albites occur, as they do in some of the albite-schists; but it may be doubted whether this mineral is due to contact action.

"The light-coloured folia represent in most cases the more calcareous laminae of the original sediments. They are rich in minerals of the type usually occurring in impure limestones which have been subjected to contact action. A colourless or pale-green pyroxene, and a colourless garnet are the two most characteristic minerals, but epidote and hornblende also occur. The pyroxene is usually present in small grains, and only occasionally attains dimensions large enough to show characteristic cleavages and optic properties. Under these circumstances,

* *Op. cit.*, p. 89.

(Mr. Teall
on Banded
Calcareous
Series.)

it is not always easy, in the absence of colour, to distinguish the pyroxene from a mineral of the epidote-zoisite group.

"Where carbonates have been preserved, which, however, is rarely the case, a narrow zone of granular pyroxene may be frequently seen separating them from quartz. The garnet is colourless, and often shows the anomalous double-refraction of grossularite. Like the pyroxene, it forms narrow zones round a carbonate, with respect to which it is idiomorphic.

"In some rocks [*e.g.* 8238] epidote takes the place of pyroxene, and the pale yellow folia are then formed of epidosite,—a rock composed of epidote and quartz. One or two specimens contain large crystals of apatite, which appear to have been developed *in situ*, for they are too large to be regarded as original elastic constituents. Sphene is sometimes an important accessory, and is often deeply coloured and idiomorphic. The other minerals, of which quartz and hornblende are the most important, do not call for special notice.

"One specimen belonging to this group [8251] is of exceptional interest.* It is a rock of compound origin, consisting of igneous and sedimentary material most intimately interblended. Thin folia, largely composed of granitic material, may be seen traversing the banded hornfels of the normal type, parallel to the banding. But there is no sharp line of demarcation between the two, although the granitic folia are coarser in grain than those which consist of sedimentary material. Under the microscope the interblending of the two kinds of material is very obvious. To the granite must be referred orthoclase, oligoclase, biotite in large plates, and some of the quartz; to the sedimentary rock, biotite in minute scales and aggregates, granular pyroxene, and the remainder of the quartz. The sphene and hornblende probably also belong mainly to the sedimentary rock. It is especially worthy of note that, although the granitic folia are only two or three millimetres in breadth, the individuals are as large as those occurring in ordinary granite (1 or 2 mms.). This clearly shows that the whole rock must have been subjected to the physical conditions under which the granite consolidated. The granitic invasion has clearly followed by preference the calcareous folia, for the granular pyroxene occurs abundantly as inclusions in all the granitic minerals except the biotite, whereas the dark purplish bands of biotite-hornfels retain their normal character, and do not show the same tendency to blend with the granitic constituents.

"That a granitic magma should possess the power of eating up limestone we can well understand, but it is doubtful whether that power can be appealed to in the present case as an explanation of the facts above referred to, for the granitic magma does not appear to have changed its composition. It is now represented by the same minerals as those of normal granite, and

* This specimen was obtained at the granite contact from the ridge due east of the Cruachan burn.

the pyroxene of the calc-silicate-hornfels merely occurs as inclusions in these granitic minerals. There is, therefore, direct evidence that the lime has never been incorporated in the magma. Seeing, however, that the granite of the district is associated with quartz-diorites and basic diorites, it becomes important to ascertain whether these rocks may be due to the absorption of sedimentary rocks.

(Mr. Teall on Banded Calcareous Series.)

"In any case, we are here dealing with a rock of compound origin. It is neither an igneous rock nor a sedimentary rock, but a mixture of the two.

"Attention was directed to the existence of such rocks many years ago by M. MICHEL LEVY,* who recognised two types. In the one the granitic material has been so to speak superposed upon the sedimentary rock, so that the contact materials float in a granitic matrix (superposition). In the other type the injection has taken place between the folia (injection "lit par lit"). Both these types are represented in this specimen. The granitic material has penetrated the sedimentary rock between the thin bands of biotite-hornfels, and has, moreover, superposed itself to some extent upon the bands of calc-silicate-hornfels, so that the contact-pyroxene occurs as inclusions in the orthoclase, oligoclase, and quartz of the granite."

PROFESSOR LACROIX, to whose observations on the granite of the Pyrenees reference has already been made in connexion with the diorite of Ben-a-Bhuridh, has also described cases in association with contact phenomena very similar to that now under consideration.† He describes passages between schists impregnated with granite, and granite impregnated with schist, and says that feldspathisation of the schists has been caused (a) by imbibition, (b) by injection—i.e., by granitic material injected between the laminae (injection "lit par lit").

In the banded calcareous series of the Pass of Brander bands are frequently met with, sometimes a few feet in thickness, of more or less pure limestone. This material is found to be converted into a finely crystalline, nearly white or greyish marble (Cipolin). A specimen, one-sixth of a mile from the granite, from the ridge east of Cruachan Burn, is a crystalline granular aggregate of calcite, with some irregular grains of diopside, and a few flakes of mica.

The *Black Schists* are found near the granite to be altered into dark compact hornfels, in which quartzose lenticles are often present. Where arenaceous material has been interlaminated with argillaceous, a more or less compact hornfels has resulted with strongly-marked dark and pale, or sometimes reddish bands. A specimen of the altered black schist from the south side of Ben-a-Bhuridh, is a dark compact hornfels with quartzose lenticles. MR. TEALL reports that under the microscope, "the dark hornfels is seen to be thickly crowded with black opaque particles and

(Mr. Teall on the Black Schists.)

* Sur les Schistes Micacés des Environs de Saint-Léon (Allier). *Bull. Soc. Geol. France*, 1881, pp. 181-196.

† Lacroix. *Op. cit.*, p. 8.

(Mr. Teall
on the Black
Schista.)

patches. The substratum in which these particles lie is crystalline, but the minerals are not easy to identify. Amongst them are two colourless minerals which differ markedly in their refractive indices, and one of which may be felspar. The quartzose lenticles are aggregates of quartz with films and patches of a pale coloured biotite often occurring in small scales. The distribution of these films shows that the rock was puckered, and in some cases the films may be traced as inclusions through comparatively large individuals of quartz, thus proving that to some extent at least the crystallisation was subsequent to the movement." MR. TEALL is inclined to think that the two doubtful minerals are felspar, and a pale biotite. If so, this would bring the rock into relation with the altered black schist of the Braemar (Glen Callater) area.

A dark, compact, banded hornfels, from the south side of the Pass of Brander, shows strain-slip cleavage, and was doubtless originally composed of alternating gritty and argillaceous layers. The former are now composed of quartz grains and minute scales of chloritic and micaceous minerals. The argillaceous layers are mainly composed of chloritic and micaceous minerals, amongst which brown mica may be recognised. The effect of the contact action has been to destroy to a great extent the previous schistosity of the rocks. Some reddish bands which occur in the hornfels of this type consist of a granulitic aggregate of quartz and turbid felspar, while epidote, zircon, and sphene occur as accessories. These bands probably represent laminae of a fine-grained felspathic sandstone.

(Mr. Teall
on Cordierite
Rocks con-
taining
Corundum.)

The *Cordierite-bearing rocks* which occur among the altered sediments (quartzose schists, biotite-hornfels, &c.) of the eastern and northern portions of Monadh Driseag, at the back of Loch Awe Hotel, have been carefully studied by MR. TEALL who furnishes the following report regarding them :

"Another very interesting type of metamorphic rock, is characterised by the presence of cordierite. This type is represented by medium-grained, often bluish-grey, fairly massive rocks, of which a specimen from the north-east side of Monadh Driseag [8254] may be selected as a type. Under the microscope one sees an aggregate of colourless minerals, in which lie detached scales and nests of biotite, and patches crowded with small grains and imperfect crystals of a green spinelle. The colourless minerals are cordierite, alkali-felspar, and oligoclase. The individuals vary in size, often measuring one or two mms. across, but rarely show any trace of crystalline form. The cordierite contains biotite, often in minute rounded scales, spinelle, and zircon, as inclusions. It is difficult in an ordinary slide to distinguish in all cases the felspar from the cordierite, as both have approximately the same refractive and double-refractive power. The characteristic yellow pleochroic halos surrounding the zircons in the cordierite are then the most useful means of distinguishing between the two minerals. But if a thin slice be heated on platinum foil, a change is produced in the cordierite. The pleochroic halos disappear, and a faint yellow colour seen best in one position of the polariser



is developed all over the mineral. This faint general pleochroism, (Mr. Teall produced by heating, is not so marked as that of the halos, but is sufficient to distinguish the cordierite from the felspar, which remains absolutely colourless. In this way it can be shown that half, or possibly even more than half of the entire rock is composed of cordierite. Of the feldspars, orthoclase is the most abundant. Pyrite occurs in grains, and as irregular masses wedged in between the other constituents. Quartz has not been observed in the specimen selected as a type.

(Mr. Teall on Cordierite Rocks containing Corundum.)

"The occurrence in a slide [8254] of this rock of one or two colourless grains with very high refractive and moderate double-refractive power, led to a search for *corundum*, which proved successful. The coarsely-powdered rock was treated for about forty-eight hours with hydrofluoric acid, and the residue boiled with nitric acid to remove the pyrite. As the microscope disclosed the presence of some corroded fragments of andalusite, the powder was placed in methylene-iodide of sp. gr. 3.315. The final residue was then found to consist of corundum, green spinelle, and one or two crystals of rutile. The corundum occurs in irregular grains and crystals up to .3 mm. in diameter. The crystals show a tendency to a tabular form, with hexagonal outlines (*see* Plate I). Those which are lying flat on the slide, and which show this outline, appear dark under crossed nicols, and give as a rule a negative uniaxial figure. Parallel striations in three directions at right angles to the sides of the hexagon may frequently be observed. These are in most, if not in all cases, due to repeated alternations of the rhombohedral and basal planes, in which the latter usually predominate. In this way a stair-like termination to the hexagonal prism is often produced."

The crystals represented on Plate I. have been drawn by MR. GILBERT WILLIAMS direct from the microscope. No. 1 shows a crystal which is well developed on the right hand side. Faces of the hexagonal prism ($11\bar{2}0$), the primitive rhombohedron ($10\bar{1}1$), and the basal plane (0001) can be definitely recognised.

No. 2 illustrates, in a very perfect manner, the step-like arrangement on the basal plane due to the alternate development of this face and the faces of a rhombohedron. This grain contains inclusions of spinelle.

No. 3 is a flat crystal bounded by the faces of the prism and showing on its basal plane the well known rhombohedral striations, which are also seen in No. 5.

No. 4 represents one of the more irregular forms with rounded angles and transverse grooves. It is evidently a portion of a rude hexagonal prism.

"The forms observed are those of a hexagonal prism ($11\bar{2}0$), a rhombohedron ($10\bar{1}1$), and the basal pinacoid (0001)—a characteristic combination for corundum, and one commonly seen in the Burma rubies and Montana sapphires. The steep pyramidal planes, so characteristic of the Ceylon and Kashmir sapphires and the common corundums of Madras, have not been observed. Inclusions of green spinelle and cavities, usually irregular, but sometimes in the form of negative crystals, are not infrequent.

"Other specimens of the cordierite-hornfels differ from the type in the relative proportions of the different constituents, in the presence of quartz, sometimes considerably abundant, and

(Mr. Teall
on Cordierite
Rocks con-
taining
Corundum.)

to a certain extent also in structure. One specimen [7618] is especially interesting as furnishing conclusive evidence as to the relative age of the crystallisation of the cordierite and the movements which have so powerfully affected the sedimentary rocks of the district. Apart from a few large patches of pyrite and flakes of biotite ($\cdot 4$ mm), this rock is composed of extremely minute opaque grains and plates (ilmenite $\cdot 01$ – $\cdot 02$ mm.) scattered through a granulitic aggregate of cordierite, quartz, andalusite, and felspar. Sometimes the grains of cordierite attain a considerable size, and then the section loses its granulitic character. Sericitic mica, zircon, and rutile occur as accessory constituents.

"The distribution of the minute opaque particles clearly shows that the rock was puckered with the occasional development of strain-slip cleavage, but this puckering has had no effect whatever on the cordierite, or on the other colourless constituents. All these in their present form have been clearly developed since the movement took place.

"This rock is interesting from another point of view. Puckering of the type here revealed is only known in phyllites and slates—that is, in rocks which were originally fine-grained sediments rich in argillaceous material. Out of such sediments the cordierite-bearing rocks have doubtless been formed, the alkali of the micaceous minerals going to form felspar, while some, or all, of the magnesia present combined with alumina and silica to form cordierite. The poverty of this rock in micaceous minerals, so common in the phyllites, is thus explained, and the simultaneous formation of cordierite and alkali-felspar is accounted for.

"In the *Explanation of Sheet 75* of the Geological Survey of Scotland (1896) a general account of the characters and distribution of the cordierite-bearing rocks of Scotland, so far as these were known at the time, was given. Since that date MR. BARROW has sent up another series from Sheet 65 (Aberdeen and Forfar). They present many points of resemblance to the rocks above described. There is the same association of cordierite, andalusite, biotite, and a green spinelle, with a variable amount of quartz and felspar; but the rocks are coarser in grain and always contain sillimanite, sometimes also garnet. One of these rocks [7085], containing cordierite, sillimanite, andalusite, felspar, biotite, ilmenite, and the green spinelle, was analysed, and the analysis is quoted as throwing light on the composition of the original sediment. It agrees remarkably with the analysis of a cordierite contact-rock from Monte Aviolo, described by SALOMON, which is quoted for comparison.

	I.			II.		
SiO ₂	...	...	...	42·08	...	44·62
TiO ₂	...	...	...	2·16	...	2·04
Al ₂ O ₃	...	...	...	32·40	...	33·33
Fe ₂ O ₃	...	...	...	13·44	{ ...	7·32
FeO	...	...	...		{ ...	5·45
MgO	...	...	...	3·30	...	5·46
CaO	...	...	...	1·42	...	0·12
K ₂ O	...	...	...	2·20	...	0·68
Na ₂ O	...	...	...	1·60	...	0·53
Ignition	...	...	...	1·60	...	1·47
				<u>100·20</u>		<u>101·02</u>

- I. Cordierite-gneiss, from the north end of Black Hill, Aberdeenshire. (Mr. Teall on Cordierite
[TEALL.] Rocks con-
II. Cordierit-contactfels, Monte Aviole. "Geologische und Petro- taining
graphische Studien am Monte Aviole," von W. SALOMON. *Zeit. Deutsch. Corundum.*)
Geol. Gesell., 1890, p. 502.

"The principal difference between the two analyses lies in the greater amount of alkali in the Scottish rock. But SALOMON states that his specimen was specially selected on account of its containing very little felspar and less biotite than the average rocks of the group: so that, if an average rock had been selected, the agreement might have been still closer.

"The close correspondence between the cordierite-bearing rocks of the Ben Cruachan area and those of Monte Aviole is especially interesting, because in both cases the granitic rock is of the same type. It is a tonalite or quartz-mica-diorite, rather than a true granite.

"There is another point of some interest which deserves mention in this connection. In the *Explanation to Sheet 75* (Scotland) special attention was directed to a rock of compound origin belonging to this group [3693]. 'The igneous portion is represented by more or less idiomorphic oligoclase, biotite, micro-poikilitic orthoclase, and quartz; the metamorphic portion by cordierite, quartz, biotite, sillimanite, and a green spinelle. The rock into which the granitic magma was intruded is now represented by somewhat ill-defined shreds, patches, and streaks, in a paste of igneous origin' (*l.c.*, p. 37). It is not possible to distinguish igneous from sedimentary material in the Ben Cruachan specimens, nevertheless something of the same kind as that above referred to may have taken place, especially as there is direct evidence that this has been the case with the bands of pyroxene-hornfels in the 'banded series.' We thus see that the cordierite-bearing contact-rocks, which always belong to the inner zones of contact metamorphism, and often occur at the actual junction, are peculiarly liable to be invaded by igneous material and more or less broken up. SALOMON describes inclusions of the cordierite rocks in the tonalite of Monte Aviole, and concludes from the occurrence of garnets and large crystals of biotite in a zone surrounding these inclusions, that the composition of the tonalite-magma was modified by the absorption of some of the contact material.

"Under these circumstances it is particularly interesting to note that cordierite, in association with the same minerals—sillimanite, green spinelle, orthoclase, plagioclase, etc.—occurs frequently in the ejected blocks of the Laacher See*, and as inclusions in the andesites and less frequently in the trachytes of the Eifel and Siebengebirge†. Mineral aggregates of cordierite, andalusite, sillimanite, felspar, biotite, pleonaste, corundum, rutile, quartz, garnet, zircon, and magnetite, bearing the closest

* "Mikroskopische Untersuchung der aus krystallinischen Gesteinen herrührenden Auswürflinge des Laacher Sees"; von Carl Dittmar. *Verh. d. Naturh. Vereines.* Bonn. 1887, p. 499.

† Beiträge zur Kenntniss der Trachyt und Basaltgesteine des hohen Eifel. Carl Vogelsang. *Zeit. deutsch. geol. Gesell.* 1890, p. 1.

(Mr. Teall
on Cordierite
Rocks con-
taining
Corundum.)

resemblance to the contact-rocks of Monte Aviolo and Ben Cruachan, occur as fragments and 'schlieren' in the hornblende-andesite of Bocksberg and Reugensfeld in the Eifel (Vogelsang). The fragments are usually rounded, but sometimes angular. They may attain a diameter of 6cms., while the 'schlieren' may be 10cms. in length. The larger fragments are often easily separable from the matrix, but the 'schlieren' may be most intimately blended with it. These inclusions vary in size, and are often so small as to be only recognisable under the microscope. It seems impossible to avoid the conclusion that we see in the process which goes on at the contact of plutonic rocks, the agency by which inclusions of the kind described by Vogelsang are introduced into igneous magmas and it is certainly remarkable, though possibly only an accidental coincidence, that the hornblende-andesites of the Eifel should be the volcanic representatives of a tonalite magma similar to that which formed the masses of Monte Aviolo and Ben Cruachan.

"This is not the place to enter upon a general discussion of the natural history of the cordierite-bearing rocks, but one or two remarks may perhaps be permitted. The mineral occurs in many igneous rocks such as granite, quartz-felsite (Cornwall), liparite, kersantite; and although in some of these it is clearly not the result of crystallisation from the normal igneous magma, in others it possesses all the characters of a mineral so formed. This, for example, is the case of the cordierite of the kersantite of Michaelstein in the Hartz, where it occurs in idiomorphic crystals. Nevertheless, a doubt is suggested as to whether, even in this case, it can be regarded as a mineral belonging to the igneous magma, for the rock in which it occurs contains numerous inclusions, made up of sillimanite, andalusite, kyanite, spinelle, and other minerals, usually associated with cordierite in contact rocks and crystalline schists. Moreover, the mineral itself contains spinelle as inclusions. It seems probable therefore that in some way or other the presence of cordierite in the kersantite of Michaelstein is due to the influence of the contact rocks upon the igneous magma, in which case it must be regarded as an endomorphic contact mineral.

"Apart from the somewhat rare and sporadic occurrence of cordierite in ejected blocks and igneous rocks, we find the mineral in crystalline schists of doubtful origin, and in contact-rocks. Its mode of origin in the latter case is fairly clear. It has been produced by the metamorphosis of sedimentary rocks, containing argillaceous material. The presence of 2 or 3 per cent. of magnesia is common in slates and shales, and as 3 per cent. of magnesia is sufficient to make about 20 per cent. of cordierite, when combined with silica, alumina, and iron, it is clear that rocks of this type furnish the necessary chemical conditions. Do these facts throw light on the origin of the crystalline schists containing cordierite--on the origin of the cordierite-gneisses? It is probable that they do, especially when taken in connection with the evidence of the tendency of the igneous magmas to

invade, and even impregnate, the rocks of the inner contact-zone. (Mr. Teall on Cordierite Rocks containing Corundum.) Suppose the phenomena of metamorphism, injection, and impregnation, which must have taken place round the Cruachan mass, to be intensified and accompanied by plastic deformation,—have we not then a rational explanation of the origin of many of the complex groups of crystalline schists which cannot be definitely classed as the metamorphosed representatives of either igneous or sedimentary rocks? ”*

Allusion has already been made to a large mass of epidiorite which MR. KYNASTON has found on the upper part of Ben-a-Bhuridh and in the corries to the north-east, as an inclusion within the granite. A general description of the rock was also given from his notes in the *Summary of Progress* for 1897 (pp. 90, 91). The exact degree of alteration which this epidiorite has undergone owing to the granite intrusion is very difficult to ascertain, owing to the great amount of variation in the rock-mass. Thus, along its southern and south-eastern borders it is exceedingly rich in hornblende, while towards the opposite margin it is extremely felspathic, often showing little or no hornblende to the naked eye. The Epidiorites. (Mr. Kynaston.)

In the crags above Allt Mhoile the sill is exposed as a grey, more or less foliated rock, with indications of porphyritic feldspars. Under the microscope [8258] MR. TEALL has observed “a few large and more or less turbid phenocrysts of plagioclase, often with irregular borders, in a ground-mass of microcrystalline quartz, feldspar, biotite, and iron-ores. There are also two or three patches of micropoikilitic hornblende.” The rock is well exposed also in the Allt Mhoile burn as a grey, fine-grained gneissose schist. Under the microscope similar ill-defined phenocrysts of plagioclase are seen, as in the preceding specimen. The ground-mass consists of a granular aggregate of quartz, orthoclase, plagioclase, biotite, and hornblende, with sphene, iron-ores, and sometimes augite, as accessories. The augite occurs as cores in the patches of hornblende, which is compact and often micropoikilitic. One specimen has a vein-like portion running through it, which does not show under the microscope any sharp line of demarcation between the two types of rock, but contains a fair amount of orthoclase. This would suggest an admixture of granitic material.

Specimens were also examined by MR. TEALL from one of the small sills on the south side of Ben-a-Bhuridh, outside the main mass of the granite. About a mile from the contact with the granite, the rock is a normal foliated epidiorite, with epidote and chlorite, and shows no signs of contact-action. At a third of a mile from the granite-contact brown mica is very characteristic, and the rock is very hard and compact, but otherwise it does

* Since this account of the Argyllshire rocks was written an important paper by DR. MOROSEWICZ has appeared (*Tschermak, Min. Mitth.* vol. xviii. (1898), pp. 1-90 and 105-240), in which some of the conclusions expressed above are more or less anticipated and greatly strengthened by experimental research.

The Epidiorites. (Mr Kynaston.)

not differ markedly from many of the epidiorites of the neighbourhood. So far it has not been possible to procure actual contact specimens of any of these smaller sills.

2. *Glen Etive Area*.—The mapping of this area has not yet proceeded far enough to give any very conclusive results with regard to the behaviour of the sedimentary rocks outside the margin of the Cruachan type of granite. Specimens of the series of pinkish gneissic-looking rocks (*ante*, p. 79), from the upper portions of some of the burns draining the western side of Glen Etive, are described by MR. TEALL as fine-grained, grey, gneissose hornfels. Under the microscope, a slide is seen to consist of quartz, andalusite (micropoikilitic), white mica, biotite, and magnetite. One specimen [8269] contains cordierite.

A specimen of the garnetiferous mica-schist from Clach-nan-Meirleach, about half a mile from the granite, is described by MR. TEALL as a "schistose, micaceous hornfels, with large patches of biotite which sometimes lie across the foliation." Under the microscope, we see "quartz, biotite, white mica, and magnetite. The main mass of the rock is markedly foliated, but the folia sometimes wind round non-foliated patches composed of the same constituents, but with more magnetite. These patches are probably pseudomorphs after garnet." Occasionally [8271] these patches "enclose cores of unaltered garnet. It seems probable that the rock was originally a garnetiferous mica-schist, that the garnets were more or less decomposed, and that the rock was then subjected to contact metamorphism."

There is thus conclusive evidence of very decided contact-action, wherever the ground immediately bounding the Ben Cruachan type of granite has so far been examined. In the Pass of Brander, and the area bounding the eastern spurs of Ben Cruachan, this action is shown by MR. TEALL'S detailed researches to have been exceedingly intense. The sedimentary rocks may be followed from their comparatively unaltered condition, as in the neighbourhood of Kilchrenan and other parts of Lochaweside, into the various varieties of hornfels, some containing cordierite, of the Pass of Brander and slopes of Ben-a-Bhuridh. The hornfels-alteration of similar rocks with production of cordierite is again found to have taken place along the granite margin, in the neighbourhood of Bonawe, and along the western slopes of the Ben Duirinnis, on the north-west side of Loch Etive (*Summary of Progress* for 1897, p. 89), and a cordierite-hornfels has also been observed in the Glen Etive area. In this latter area, however, the contact-zone is not so well marked as it is further to the south-west, since evidently here the sediments had undergone the action of the forces of dynamic metamorphism to a far greater degree, and were already in the condition of highly crystalline schists previous to the intrusion of the granite. It is true that our knowledge of the district is by no means complete, so that it would be premature at present to enter into a discussion of the relative effects of the metamorphosing forces which have affected the rocks. Whatever these may have been, there can hardly be any doubt that the different varieties

of hornfels above described owe their peculiar and characteristic features directly to the contact-action which took place at the time of the intrusion of the Ben Cruachan granite. The Epidiorites (Mr. Kynaston).

Isle of Arran.

The remaining area of Old Red Sandstone mapped by the Geological Survey during the past year in Scotland lies in the island of Arran, where MR. GUNN has been engaged in continuation of the field-work described in previous *Annual Reports*. (Mr. Gunn.) A belt of Old Red Sandstone sweeps across the centre of the island to the west coast. Near Dougrie on that side it seems all to belong to the lower division of the formation, characterised by thick bands of coarse quartzite-conglomerate, alternating with red and purple sandstones. The total thickness of these strata amounts to several thousand feet. The coarse conglomerates are unusually thick on the hill called Garbh Thorr, near Monyquill. Good exposures of the rock are to be seen in the old sea-cliffs south-east of Dougrie, where the beds dip south-south-west at high angles and are in places vertical.

In the course of the field-work of last season MR. GUNN has made the discovery that near Auchencar this group of the Lower Old Red Sandstone includes a volcanic platform. He has traced a band of lava eastward for about two and a half miles, as far as to the north-west side of Garbh Thorr, and found it everywhere apparently underlying the main mass of the conglomerates, while the strata below it consist principally of sandstones. Where this lava appears at the surface it is largely amygdaloidal and of an andesitic character, though the lower part of it is in places compact and seems more basic than the rest. The best section has been cut by the Auchencar Burn about seventy yards east of the moor fence, where a thickness of from fifty to sixty feet of the volcanic material is exposed. The rock is amygdaloidal above and compact below. As the lava-sheet is nearly vertical it occupies but a narrow strip of ground, and, moreover, is a good deal concealed by drift. Still, traces of it may be detected in several places to the eastward, and unmistakable outcrops of it occur to the north of a conglomerate hill called Baniorlach, and likewise to the north-west of Garbh Thorr, where the band seems to be thicker than in the Auchencar Burn.

In the conglomerates above this volcanic zone pebbles of an andesitic rock, which have probably been derived from the lava, are common. Not improbably the volcanic material was extensively denuded before and during the formation of these conglomerates. The discovery of this band increases the number of the volcanic horizons in Arran to at least five: two in the Old Red Sandstone and three in the Carboniferous system; while to these must be added the great series of much younger (probably Tertiary) intrusive rocks.

South Wales.

(Mr. Cantrill.) In the re-survey of the South Wales coal-field portions of the surrounding tracts of Old Red Sandstone require to be mapped in order to complete the sheets of the one-inch map. During last year MR. CANTRILL was engaged upon this work in the district which extends from the valley of the Nêdd to that of the Twrch. Though it mainly lies on a dip-slope that drains southwards, this district includes the headwaters of the rivers Senni, Crai, and Sawdde, which rise on the north side of the escarpment of the Fans.

The lowest beds of the Old Red Sandstone which come to the surface in this area, consist of sandstones, shales, and marls, usually green, but occasionally dull-red, with green or red conglomeratic conglstones. They are exposed in Glyn Senni, Cwm Crai, and Blaen Tawe, while on Cefn Cûl some of the green sandstones have been quarried for roofing, paving, etc. The upper limit of these green strata is somewhat indefinite, and the series seems to belong rather to the upper arenaceous division of the Old Red Sandstone than to the lower part of that formation, in which red marls predominate. Above the green beds lies a great thickness of red sandstones, shales, and marls, with thin red calcareous bands at rare intervals. These strata form the great scarp of which Fan Gihirych, Fan Hir, and Fan Sir Gaer are prominent points. In their lower part they include some incoherent quartz-conglomerates, well seen near Llyn y Fan Fawr, while at about 50 feet from their top a pebbly grit runs near the top of the scarp of Fan Gihirych, and at the top of that of Fan Hir, where some of its pebbles are as large as hen's eggs. Conglomerates were first met with at this horizon in the Hepste valley (*Summary of Progress* for 1897, p. 95); the pebbles consist almost wholly of vein-quartz.

The highest subdivision of the Old Red Sandstone, the "grey grits and conglomerates," almost disappears a little west of the Taf fawr, as previously reported, but in Cwm Byfre it is 24 feet thick, and it exists also in the valleys of the Haffes, Giedd, and Twrch. In Glyn Tawe and two other valleys further west it is clearly seen to be superimposed upon and not replaced by the red conglomerates described above. As has been mentioned in former *Annual Reports*, the strata of this subdivision resemble some quartz-conglomerates which are interstratified in the limestone, and therefore suggest a transition from the Old Red Sandstone into the Carboniferous system.

On the south side of the Coal-field MR. CANTRILL has mapped a small anticlinal tract of Old Red Sandstone on Stalling Down, east of Cowbridge, where red sandstones and grits, with quartz-pebbles, belonging to the upper part of the formation, are exposed.

DEVONIAN.

The re-survey of the counties of Devon and Cornwall has involved a re-examination of the Devonian rocks which are

restricted to that part of the United Kingdom. In Devonshire the stratigraphy of these rocks has been worked out by MR. USSHER as far as possible on a basis of palæontological evidence. But large areas in that county, and still more in Cornwall, have not yielded any organic remains, so that the geological position of the sedimentary rocks is by no means absolutely determined. On the published Survey maps the general body of strata has been coloured as Devonian, but it may be eventually possible to show that they include masses of much older date. In the meantime it is most convenient to keep the whole series under the old name until more precise information on the subject has been obtained.

Devon and
Cornwall.
(Mr. W. A. E.
Ussher.)

MR. USSHER has prosecuted the revision of the western margin of Devonshire and the eastern borders of Cornwall, in the district between Princetown and Gunnislake. He has been engaged upon Upper Devonian slates, schalsteins, and "greenstones," together with tracts of Culm-measures and granite.

In this district the Upper Devonian strata consist of fine-grained slates normally of a pale greenish colour. They are traversed by planes of schistosity frequently horizontal and very seldom inclined at high angles. This tendency to horizontality in these planes is the rule throughout the ground to the west of Dartmoor. It is also apparent in the volcanic rocks and Culm-measures, in which the tendency to present more or less horizontal planes is due to the sharp, irregularly zig-zagged structure of the smaller folds. The bedding may therefore be in reality more or less vertical in the limbs of innumerable repeating folds which cannot be actually traced.

The Upper Devonian slates are exceedingly unfossiliferous; obscure organic remains were detected by MR. USSHER in only one or two places.

The relation of the Devonian slates to the volcanic rocks and Culm-measures, even where the rocks are visible at the surface, is obscured by faults, so that no actual succession can anywhere be obtained in the area recently surveyed. Within the aureole of metamorphism round the granite the lines of boundary between the several groups of rock are hardly capable of precise delineation. Viewing the evidence obtained from other districts, and taking what seems to be the most probable inference from the complex character of the Tavistock volcanic area, MR. USSHER is disposed to regard the volcanic rocks as most probably intermediate between the Upper Devonian formations and the Culm-measures. The earliest eruptions may have begun in the Upper Devonian period, but the main part of the volcanic history was probably contemporaneous with the lower portion of the Culm-measures.

The volcanic rocks of the Tavistock area consist of more or less vesicular schalsteins, the vesicles being often filled with calcite. With these bands a little compact greenish limestone is locally associated, apparently near the base of the series, as if the calcareous material represented Upper Devonian limestone, deposited in intervals between the earliest outflows of lava

Devon and
Cornwall.
(Mr. W. A. E.
Ussher.)

Examples of this association of calcareous material are visible by the River Tavy, on the south side of Abbey Bridge, Tavistock, and by the side of the high road W.N.W. of Tavistock, near the second milestone at the turning to Langford. This point is of considerable interest, especially in connection with the origin of the curious and exceptional rock (2764) described by MR. TEALL (*Annual Report of the Geological Survey for 1896*, p. 52). That rock may perhaps have owed its origin and composition to the mingling of basic volcanic dust with calcareous detritus on the floor of the sea.

At and near Tavistock the association of hard dark, sometimes cherty Culm-measures with the volcanic rocks 'is so intimate as to suggest that lenticular patches of the one kind of rock have been interstratified in the other, but the zigzag bedding structure renders this supposition rather doubtful, for the effect might have been produced by the truncation of sharp plications. Be this as it may, there is every reason to conclude that the volcanic rocks with their associated dark basement Culm beds and schistose greenstones have been converted in part within the aureole of metamorphism round the granite into such types as have been described by MR. TEALL (Nos. 2762, 2763, and 2765 in the *Annual Report* above cited, p. 52).

Cox Tor Moor exhibits masses of altered greenstone (Gabbro) and varieties of the hard rocks mentioned in the same *Report* (p. 51). For these hard rocks and their different varieties it is proposed to employ the term "Peak Hill rocks," as they form that summit on the border of Dartmoor near Dousland. Although they were for the first time petrographically discriminated and described in the Geological Survey's *Annual Report* for 1896, these peculiar rocks had already been alluded to by the late A. CHAMPERNOWNE and described on his MS. map of Brent as "porcellanized rocks." Since 1893, the occurrence of rocks of this nature near Brent, Wrangaton (Kingsbridge Road), Ivy-bridge, and Cornwood has been a source of perplexity, owing to the apparent intercalation of inconstant bands among Upper Devonian Slates in a railway-cutting south of Brent (*Annual Report* for 1895, p. 7), and to the occurrence of a similar collocation in the upper part of a slate-quarry $2\frac{1}{4}$ miles east of Tavistock. These appearances might be explained by contortion, but if, as there seems now to be little reason to doubt, the Peak Hill rocks are altered representatives of the volcanic series and basement Culm-measures of Tavistock, the local association of bands of volcanic rock with fine calcareous matter in the uppermost part of the Upper Devonian Slates need cause no surprise. It is confidently anticipated that the detailed investigation of the rocks of the Tavistock area in the field will yield interesting results and enable the petrographer to identify the original volcanic or sedimentary materials of every variety of the Peak Hill series which is so well displayed around the greenstones of Cox Tor.

Cornwall.
(Mr. J. B.
Hill.)

The advance of the revision of Cornwall has unfortunately been retarded by the continued ill-health of MR. J. B. HILL.

This officer was able during and after his convalescence to map some of the ground left by him incomplete in Argyllshire when he was transferred to England, and which it was desirable that he should put in order for his successor there. He was thus prevented from resuming active field-work from Falmouth as his centre until the end of August. But as he had the advantage of admirable cliff-sections in his immediate neighbourhood, he was able before the end of the year to make considerable progress in the study of the complicated structure of that region.

MR. HILL has now mapped in detail the coast-line from Gerrans Bay to the Helford River, a strip little more than ten miles in length, but broken up by so many creeks that the comparatively small area has allowed of the mapping of over thirty miles of coast-sections. From that coast-strip as a base line the work has been pushed into the interior as far as the short available working season would permit.

On reference to the old geological map it will be seen that the area in question commences at the divisional line intended to separate Devonian from Silurian formations. The coast-section of the area coloured Silurian along the northern shores of Gerrans Bay has also been examined, and it may be stated briefly here that no stratigraphical break exists there, but that the strata coloured Devonian can be traced uninterruptedly into those coloured Silurian.

The section between Gerrans Bay and the Zoze Point consists of a series of blue slates with numerous alternations of harder beds containing a variable quantity of sandy material, and showing every gradation from a sandy slate to a strong grit. These strata extend eastward into the area which has been coloured Silurian. The appearance of limestones at Gidley Well and the fossiliferous quartzite at Carne serve to indicate the apparent incoming of another division of the stratigraphical series, though there is no evidence for drawing here a sharp divisional line to mark off two distinct geological formations.

For convenience of reference the strata on the north side of Gerrans Bay which have been coloured Silurian will be referred to in the following pages as the "Veryan beds," and the slates immediately to the west of them which have been coloured as Devonian will be cited as the "Portscatho slates." Besides these two divisions, two other series will be mentioned, one of which De la Beche described as the variegated slates; the other will be referred to as the Mylor series. The divisions succeed one another from east to west in the following order:—

1. Veryan Beds.
2. Portscatho Slates.
3. Variegated Slates.
4. Mylor Series.

(1) The Veryan Beds, consisting of blue slates mixed with thin limestones and a well-marked quartzite, strike into Gerrans Bay, and have not again been met with in the area now to be

Cornwall.
(Mr. J. B.
Hill.)

described. Beds similar in character, however, make their appearance on the coast south of the Helford River, near the Nare Point. These beds are probably the south-western extension of the Veryan Beds, and they appear to occupy the same relative position to the Portscatho Series as the Veryan Beds do at Gerrans Bay; but any further account of this part of the series will be reserved until after a more detailed examination of the Veryan Beds and their correlation with the strata south of the Helford River, which will be undertaken next season.

(2) The Portscatho Slates succeed the Veryan Beds to the westward, and can be traced along the coast-line southwards to the St. Anthony peninsula, and their south-westerly prolongation is met with again on the coast of Falmouth Bay opposite. They consist of blue slates with a variable admixture of sandy and fine gritty bands.

(3) The Variegated Slates which bound the Portscatho series on the westward are well seen at St. Mawes, but still better in the excellent section between Pendennis Castle and Swanpool. The prevailing blue colour of the Portscatho beds has disappeared and is replaced by tints that vary from green to grey and buff, though blue argillaceous bands are still to be seen among them. The strata consist of alternations of argillaceous and fine sandy material, the colour varying with the character of the sediment; hence the general variegated appearance of the series. The weathering is equally characteristic; the beds become extremely friable, especially those of a sandy nature, and weather into a deep buff colour. On the whole the material is finer than in the Portscatho series, the coarser grit-beds of that series being here entirely absent. Within the Variegated Slates a narrow zone of sharply contrasted purple and green slates has been observed at St. Mawes and in the large dry dock at Falmouth. This zone is only a few yards in breadth, and has not been noticed save at these localities. It has been found of value, however, as an aid in correlating the variegated slates of Falmouth with those of St. Mawes which are separated by the Carrick Roads, a sheet of water more than a mile broad. The Variegated Slates of St. Mawes contain less of the buff sandy material than the Falmouth section, and are only marked off from the Portscatho series into which they gradually merge by a prevailing pale greenish hue.

(4) The Mylor Series, the most westerly of the four divisions into which the slates of this part of Cornwall have been provisionally divided, appears on the south-west side of the Variegated beds, and has been traced in the Falmouth area right up to the boundary of the granite. It is very well seen in the coast sections of Penryn Creek between North Parade and Boyer's Cellars; also in Mylor and Restronguet Creeks. Its westerly limit outside the granite area has not yet been ascertained. It consists of dark blue and black argillaceous and fine quartzose beds. These strata often have a fine striped or ribbon-like appearance, due to the very fine alternations of tiny seams of varying material. These thin laminae are either alternations of siliceous and argillaceous material, or in some cases the differently

coloured laminæ are all argillaceous, but paler and darker in colour, those with most siliceous material weathering paler than the more purely argillaceous seams. Their most characteristic feature, however, is the presence of fragments clearly derived from the mass itself, which forms the matrix that encloses them. These fragments sometimes attain a length of five or six inches, and they graduate downwards to the size of small pebbles. As a rule they show little sign of attrition, the larger fragments being usually quite angular; the smaller are sub-angular, but sometimes even perfectly rounded. They consist both of argillaceous and of siliceous material; the latter, however, is most common, as it has offered greater resistance to the processes of disintegration. The large number of argillaceous fragments and the general absence of rounding may be taken as indicating that these materials have been transported but a short distance. The detritus is not uniformly distributed over the series, in many places it is rare or may even be absent altogether; and in such cases it is often difficult to be certain that particular beds belong to this series; but careful search will usually reveal some other characteristic, such as the presence of zones with the very fine rapid alternations of siliceous and argillaceous material. On account of the uneven character of the material in this series the slaty cleavage is not so perfect as in the other divisions.

Occasional instances of pebbles derived from the contemporaneously formed slates may be observed in the Variegated and Portscatho series; and at Rosemullion a bed occurs two or three feet in thickness, which is practically a boulder-bed not unlike those in the Dalradian series of Argyllshire and Perthshire. The pebbles are well rounded and vary in size, some attaining a length of three inches. They are made up of a hard sandy material, precisely similar both in colour and composition to the matrix in which they are embedded. This character being common to all the divisions is another evidence for linking them together in one continuous series forming part of one of the great geological formations.

It was pointed out in the account of the Cornish rocks given in the *Summary of Progress* for 1897 (which dealt almost entirely with the Portscatho series) that the slates everywhere showed evidence of intense foldings and puckerings, accompanied by innumerable minor faults. Similar evidence was met with last year in all the members of the group. Not only do the sections of each series afford ample instances of such plication, but the application of zonal mapping to the slates has brought out the fact that the large stratigraphical divisions are themselves interfolded with one another. In this way the Portscatho Slates and the Variegated Slates have been repeated in Falmouth Bay by folding. The Variegated Slates which succeed the Portscatho series uninterruptedly at St. Mawes, after being lost beneath Falmouth harbour, make their appearance again on the Pendennis peninsula, succeeding the Portscatho slates near Pendennis Castle. The junction of the two series can be followed to the south-west, and is seen on the coast midway between Pennance Point and Swanpool beach,

Cornwall.
(Mr. J. B.
Hill.)

where the variegated series stretches into the interior; while the Portscatho Beds lying to the east of them can be traced along the coast as far as Maenporth. There, however, the Variegated beds come on again on the east side of the Portscatho Slates, and after an outcrop a quarter of a mile in width make way once more for the Portscatho Beds, which are continued along the entire section to the Helford River. A thin well-marked band of the Variegated series has also been brought up again near Pennance Point, but at no very great distance from the boundary of the main band. From their agreement in strike and their inclusion of the band of purple and green slates already alluded to, there can be little doubt of the identity of the Variegated Slates at St. Mawes with those of Pendennis. The coast-sections between the Veryan Beds at Gerrans Bay and the Variegated Slates at St. Mawes are so continuous that it may be confidently believed that the Variegated Slates at Pennance Point and Maenporth, which are situated on a geological horizon east of the Variegated Slates at St. Mawes, are not represented in the section between St. Mawes and Gerrans Bay, but that these bands have "nosed out" by folding before reaching the St. Anthony peninsula, at which they strike. The Maenporth Variegated and Portscatho Slates are the repetition by folding of the main bands that pass through Falmouth.

Minor folds and faults may be detected in a careful study of the coast-sections of any of the groups, although the inclination of both limbs of each fold being generally in the same direction, the plication is not so conspicuous as in a region of well-marked anticlines and synclines. Probably for this reason, the enormous amount of folding in the Cornish slates has not hitherto apparently been suspected, and thus erroneous impressions have been formed as to the thickness of the strata. Sections without evidence of folding are rarely continuous for any distance, and as far as observation has gone there appears to be as much folding in one series as in another. Perhaps the coast between Falmouth and Swanpool offers one of the most conspicuous illustrations of folding and minor faults. Alternation in material of the sandy and argillaceous beds of the variegated series has there produced irregularity in the folds, according to varying capacity of resistance to pressure, which the variegations in colour admirably bring out. Foldings, crumplings, faults, and strain-slips are so intermingled among these strata that the detailed structure is too intricate to be unravelled on a map.

The minor folds and puckerings are well brought out in the Mylor Series, where the fine alternations of siliceous and argillaceous material, together with the inclusion of fragments, have offered a less uniform resistance to pressure than the ordinary slates have done. Hence has arisen a set of strains and structures more complicated than where the slates are uniform in character. Moreover, the rock is often full of small thrust-planes, with a tendency to a secondary cleavage, while little movement-planes appear in the core itself, as in the Highland schists, with accompanying strain-slip cleavage. The cleavage-planes pass through

the axes of the minute folds, which often culminate in small thrust-planes. The strain-slip cleavage is often as prominent as the dominant cleavage of the beds. Cornwall.
(Mr. J. B. Hill.)

Quartz-veins are abundant over the entire succession of groups of strata, but they are most abundant in the Portseatho Slates, and least so in the Mylor Series. They show a tendency to diminish in number to the westward. Most of them share in the foldings and crumplings, and many of them are full of transverse cracks. They appear to be most numerous where faulting is most prevalent. They have furnished the greater part of the material for the various shingle-beaches that occur along the coast, as well as those of the older raised beaches of the district.

The beds over the whole area surveyed have a more or less uniform dip to S.E., but in a district so folded it is hardly safe to consider the observed dips as more than inclinations of the limbs of folds. The cleavage is usually slightly oblique to the strike, and the beds are rarely so uniform in character that the bedding cannot also be ascertained. The cleavage and folding appear to have been the result of movements proceeding from a direction between E. and S.E.

The district is singularly devoid of organic remains. Except in the Veryan Beds no fossils have been discovered, with the solitary exception amongst the Mylor slates at Penryn River, where, out of numerous specimens sliced for examination under the microscope by Mr. F. J. STEPHENS, a few slides were reported to have contained Radiolaria. The Veryan Beds are noted for the discovery by the late MR. C. W. PEACH of what have been regarded as Lower Silurian fossils in the quartzite bed at Carne. These fossils consist mainly of small specimens of *Orthis*. Many of the limestones from the same locality have been sliced for microscopic examination by MR. HOWARD FOX, and although found to contain encrinital and other remains, these have proved to be of too fragmental a nature to afford definite palæontological evidence of their geological age. MR. FOX has also found and described Radiolaria in certain cherts, and crinoidal remains in some thin black shales in the Veryan Beds. Although the rocks described in the foregoing pages are unfossiliferous except in one division, they have been divided, as already stated, into two geological formations; the Veryan Beds, which contain fossils, being included amongst the Lower Silurian, while the remaining three series, in which no organic remains have been found, are included in the Devonian formations.

If the apparent dip could be taken to be of value in determining the geological position of the strata, the Veryan Beds would be the highest and therefore youngest of the series, the Mylor group being the lowest and oldest. If this could be assumed to be their correct position, the various groups of strata to the west of the Veryan group would have to be considered as Lower Silurian, or even older. It is hoped that further light on the stratigraphical relations of the Cornish slates will be obtained as the revision of the county advances.

Cornwall.
(Mr. J. B.
Hill.)

The large mass of granite which extends from Penryn to near Helston has its eastern boundary in the area that was mapped last season. In the small portion that has been examined the junction of the eruptive rock with the slates has been found to be concealed. The granite is usually grey in colour, and fairly coarse in texture, consisting of orthoclase and plagioclase, abundant quartz, and both white and black mica, with tourmaline usually present in small quantities. The felspar is sometimes porphyritic. No elvans have been observed in the granite so far as it has been examined, but a few have been mapped outside the granite area. Although the junction of the granite and slates has not yet been seen, the bulk of the slates that lie between Falmouth and the margin of the granite show no evidence of metamorphism. The slates, however, between Flushing and Penryn, as seen on both sides of Penryn Creek, are spotted, and at times crowded with ovate bodies; the particular mineral which composes these has not yet been determined. When fresh they are very hard and dark in colour, due no doubt to impurities taken from the slate. They often weather green and red, and are then quite soft. This character is the dominant type at the Flushing end of the section. The ovate bodies are fresher and larger in the neighbourhood of Penryn as they approach the granite.

Besides the granite and quartz-porphyrines, other igneous rocks occur in the district which are evidently of greater antiquity. In most cases they have been considerably metamorphosed, and are much decomposed. They have been intruded as sills, and have shared in some of the movements and alterations which have affected the surrounding slates. Of these intrusive rocks, the principal is the mass that passes in a north-easterly direction through the northern part of Falmouth, and joins the south end of Flushing, where it widens to about 200 yards and then disappears. Although fresher specimens can be obtained from this sill than from others of the same class, it is generally much altered and in parts sheared. It is finely crystalline, and its main constituents (which, however, have not yet been precisely determined) appear to be green mica and decomposing felspar, with numerous carbonates and other decomposition products. A little further to the westward two other sills, separated only by a few yards of slate, are still more highly sheared and too decomposed for their mineral character to be definitely recognised. Moreover they are interfolded with slates, which adds to the complexity of their structure. In the old map only one sill has been coloured, and not improbably the separate outcrops belong to a single sill repeated by folding. The extension of the same rock separated by slate can also be seen on the Falmouth shore. Still another sheet of similar character occurs at Boyer's Cellars, further up the creek, and one also near Trevisson in the parish of Mylor. The slates sometimes included in them might lead to the supposition that these igneous bands are tuffs, but when the amount of plication in the district is considered there does not seem to be any reason against including them with the sills in

the neighbourhood, to which they bear a relation, and the intrusive character of which is beyond question. A comparatively unaltered sill of mica-trap, seen on the coast at Mawnan, is about four feet wide, massive, and comparatively fresh. It contains inclusions of quartz and crystalline felspathic rock, some of them being well rounded; also occasional pieces of slate. Some of these fragments attain a size of two or three inches. The rock is mainly composed of fine crystals of biotite and felspar, and appears to be earlier than the various faults which traverse the slates. It bears a strong resemblance to some of the lamprophyres which have been intruded into the schists of the Scottish Highlands.

Cornwall.
(Mr. J. B. Hill.)

CARBONIFEROUS.

The present field-work of the Geological Survey in the areas occupied by the Carboniferous system throughout the United Kingdom consists almost entirely in the revision of the various coal-fields on the scale of six inches to the mile. In the following summary of the progress made last year the several areas will be taken in order from south to north.

Devonshire Culm-measures.

The most southerly district of Carboniferous rocks on which the Survey was engaged lies along the western margin of Devonshire, where MR. USSHER surveyed the Culm around Tavistock. He found the strata there to consist of (1) hard, dark, shaly, and often cherty materials, which, associated with the volcanic series already alluded to in the section on the Devonian system, form the basement portion of the Culm; (2) dark shales, sandy, lead-coloured micaceous shales and grits, composed of quartz, felspar, and mica, with a black opaque matrix. The sandstones and grits seem to be local, and irregularly intercalated in the shales. Highly altered rocks, apparently belonging to the second group, are to be seen near the granite on the north margin of Cox Tor Moor.

(Mr. Ussher.)

The exact relations of the two groups (1) and (2) are nowhere manifest, owing to faults and the absence of junction-exposures. The arenaceous Culm-measures form a considerable tract between Beer Alston and Pillaton in Cornwall, already surveyed. In that area they rest on Upper Devonian strata, while the basement Culm chert-beds occur locally in inexplicable relation to them, and also rest on Upper Devonian rocks. During the past year two places, viz., Efford, east of Plymouth, and Wearde, south of Saltash, were revisited. In both, grits or sandstones occur, which from their constituents may be called arkoses. At Wearde these rocks seem to lie directly on volcanic materials in which a marked intercalation of chert-beds was detected in one spot. MR. USSHER, from the absence of traces of plants or other

(Mr. Ussher.) organisms, was long in doubt whether to regard these rocks as a local rearrangement of siliceous tuff in the Upper Devonian series, or as Culm grits. Further study of the Culm districts now inclines him to regard them as Culm grits, and to consider the Wearde volcanic rocks as the equivalents of the Tavistock volcanic series. The only explanation which he can suggest of the occurrence of the Culm grit series, as it has been found, is that owing to irregularities of local vulcanicity during or preceding elevations of the sea-bed, the shales and grits were deposited unconformably upon basement Culm rocks or volcanic rocks, and in their absence directly upon the Upper Devonian strata. He would regard the Culm shales and grits as the base of the Middle Culm-measures, on the same general platform with the Ugbrooke Park conglomeratic beds, but he has found no proof of any break between the Middle and Basement Culm-measures of North Devon. The expression of a more definite opinion as to the relations of the Culm rocks must be postponed until the coast-section from Boscastle toward Bude has been studied in detail.

Volcanic group in the Carboniferous Limestone of North Somerset.

(The Director General and Mr. Strahan.) The existence of certain igneous rocks in the Carboniferous Limestone series of Somerset has long been known. They are represented on the published Geological Survey Maps as intrusive in origin, and they have been described as dykes. Their true nature, however, was detected as far back as 1880 by PROFESSOR SOLLAS, who recognised the rocks as volcanic tuffs and amygdaloidal lavas.* In the year 1896 the ground was examined by MR. STRAHAN in connection with the revision of the South Wales coal-field, as a portion of North Somerset is included in one of the one-inch maps of that region. From his field-notes and the specimens he collected, it was quite certain that the Carboniferous Limestone on the south side of the Bristol Channel contains records of contemporaneous volcanic activity, and reference to the subject was made in the *Annual Report* of the Geological Survey for 1896 (pp. 61, 62), but further description of the evidence was reserved until the ground could be more carefully studied.

Accordingly, in the autumn of last year the various sections where these interesting rocks are exposed were visited by the DIRECTOR GENERAL and MR. STRAHAN, whose observations may here be briefly stated inasmuch as the evidence for the contemporaneous character of the igneous intercalations has never been

* *Proc. Geol. Assoc.* vol. vi. (1880), p. 378. In the "Handbook" prepared for the meeting of the British Association in 1898 at Bristol, Prof. Lloyd Morgan has recently expressed the same opinion regarding the nature of these rocks. (*Handbook*, p. 19.)

published. The occurrence of igneous bands in the Culm measures of Devonshire has long been recognised, but these rocks have shared in the general crushing and cleavage of the whole of that region, so that their original characters are often obscured, and even their stratigraphical position is not always clear. In the Somerset district, on the contrary, the evidence is precisely similar to that of the Derbyshire toadstone region, and brings clearly before the eye successive outflows of vesicular lava, and showers of volcanic detritus over the floor of the sea in which the Carboniferous Limestone was deposited. (The Director General and Mr. Strahan.)

The district in which the volcanic rocks in question rise to the surface extends along the eastern shore of the Bristol Channel, from the limestone ridge of Middle Hope southwards for five miles to Uphill, where the western spurs of the Mendip Hills sink under the great alluvial plain. Its inland limits are uncertain, but volcanic rocks of the same age and type appear among the limestones of Wrington Warren ten miles to the east, while still further inland, certain eruptive masses have pierced the ridge of Old Red Sandstone to the north of Shepton Mallet. The actual area of sea-bottom over which volcanic eruptions took place probably far exceeded 50 square miles. There is no evidence of any central vent. On the contrary, the explosions appear to have taken place from small scattered orifices, as in other parts of the Carboniferous Limestone areas of Britain. We can recognise the probable neighbourhood of several of those active vents. One of them lay in the district of Uphill, the position of another or of more than one lay to the west of Weston-super-Mare, and to the north-west or west of the ridge of Middle Hope, while a more distant centre of eruption was situated not far from Wrington Warren.

It will be enough to give here some of the details of the more important sections. At Spring Cove, immediately to the west of the town of Weston, a cliff between the high road and the sea exposes the succession of rocks given in the subjoined table in descending order:—

Massive limestone full of fossils. The lowest three feet of the rock are crowded with fine volcanic dust, which under the microscope is seen to consist of fine vesicular lapilli.

Highly amygdaloidal altered basalt, having a "pillow"-structure, and with abundant calcareous and hæmatitic veins, and threads of carbonate of copper; about 35 or 40 feet.

Red limestone, full of fine volcanic dust, and passing down into the ordinary grey fossiliferous limestone.

This section places clearly before the mind the succession of volcanic events of which it retains the record. From some vent in the neighbourhood fine dust continued to be ejected during a considerable interval, for the limestone, through some 30 or 40 feet of its mass below the basalt, is full of disseminated volcanic particles. It may be remarked in passing that nowhere in the British Isles can more typical examples be found of the chief characteristics of the Carboniferous volcanic tuffs than in the volcanic tract of North Somerset. The lapilli abound in finely

(The Director General and Mr. Strahan.) vesicular basic pumice, and show the prevalent dull-green palagonitic modification of what was no doubt originally a basic glass.

At last a stream of lava flowed over this part of the sea-bottom. It rested immediately on the calcareous sediment to which it is now firmly bound, and which is highly crystalline; but there is no conclusive evidence that this crystalline structure has been due to the heat of the overlying lava. This lava is now much oxidised and decayed, strongly amygdaloidal, and presenting the characteristic "pillow" or sack-like structure that has been so frequently observed among the submarine volcanic eruptions of former geological periods. The interstices between the large irregularly shaped pillow-like masses of the sheet have been filled up with calcareous material, which, in the form of a network of limestone ribs with veinings of hæmatite, traverses the rock. The basalt contains also lumps of limestone, while some of its more solid parts have been broken up and have been involved in portions possessing a much more slaggy structure. The bottom of the sheet is much brecciated, the fragments being finely vesicular. The lava has been sliced and examined under the microscope by MR. TEALL, who reports regarding it as follows:—

"The lava from Spring Cove, Weston-super-Mare [E. 3212 (23)], is a fine-grained, chocolate-coloured rock, composed of pseudomorphs after olivine, and probably augite, in a groundmass showing microlitic structure. The phenocrysts are represented by pseudomorphs in carbonate. The microlitic feldspars of the groundmass are colourless, but they no longer show their characteristic optical properties. The groundmass is deeply stained with ferric oxide. Although all the minerals have been destroyed, the structure has been perfectly preserved, and there can be no doubt whatever that the original rock was an olivine-basalt."

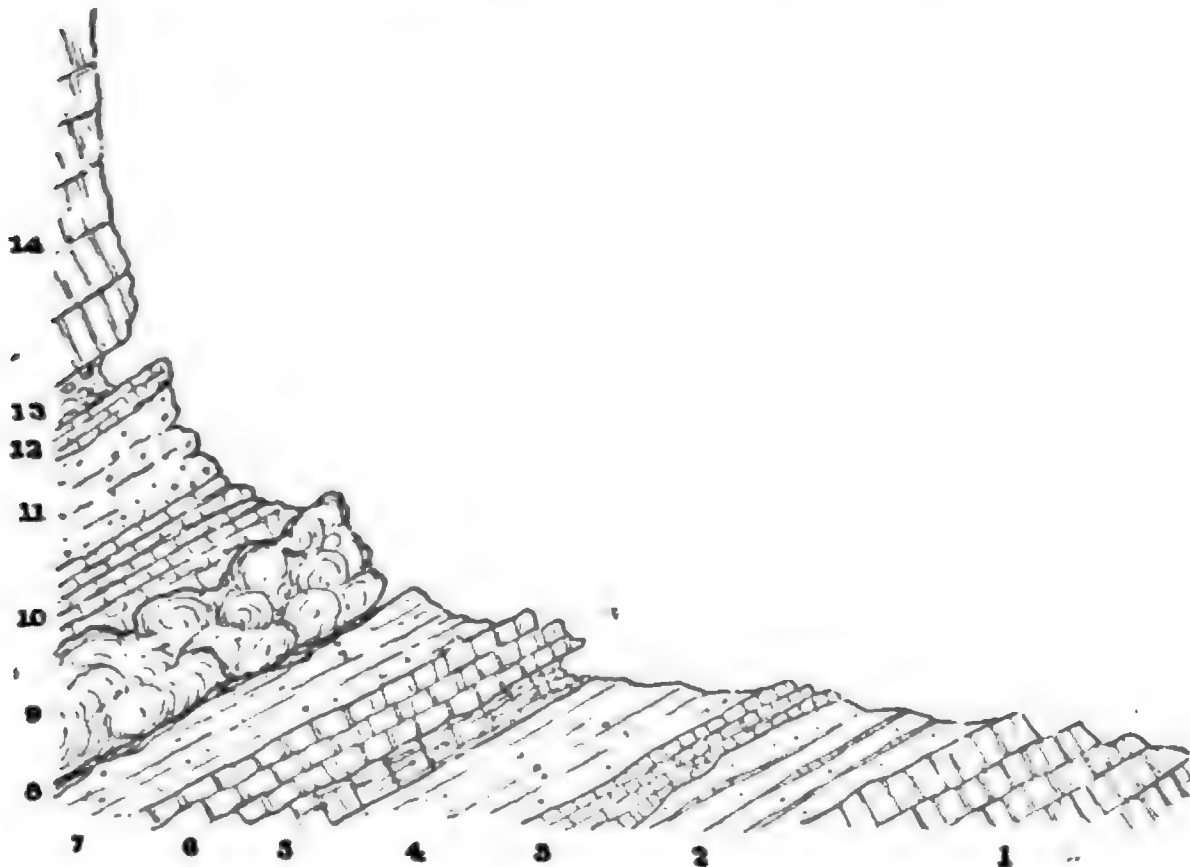
On the rugged upper surface of this basalt the limestones have been laid down in the same way as underneath. The volcanic episode, although it locally interrupted the continuity of the accumulation of organic detritus on the sea-bottom, seems to have effected no change in the general conditions of sedimentation. Fine volcanic dust appears in the overlying limestone for about three feet above the surface of the lava, and thereafter the calcareous rock assumes its usual highly fossiliferous character.

That the little vent from which the discharges took place lay to the westward, under what is now the Bristol Channel, may be inferred from the disappearance of the volcanic zone as the ground is traversed in the opposite direction. Fragments of the amygdaloid were found by Mr. SPENCER PERCEVAL at the Toll-gate, which show that this rock extends inland for a mile and a half. But immediately to the east over the bare limestone surface above Kewstoke or Milton Hill and the ground towards Worle MR. STRAHAN could find no trace of it.

Two miles to the north of Weston another parallel ridge of limestone, known as the Middle Hope, runs out into the Bristol Channel and displays along its northern coast-line a still more interesting intercalation of contemporaneous volcanic material. Three separate sections have been laid open by the sea within

the space of a mile. The most westerly of these is illustrated in the accompanying figure, which represents the whole volcanic group, about 100 feet thick, intercalated between the ordinary crinoidal limestones (1 and 14). At the base from low-

(The Director General and Mr. Strahan.)



Section of Volcanic Rocks in Carboniferous Limestone.
Middle Hope, Mouth of Severn, Somerset.

water up the beach, between 30 and 40 feet of highly fossiliferous crinoidal limestone (1) appear from under the sea in successive beds, which towards the top pass into a reddish banded limestone with thin partings of red clay. The argillaceous material probably results from decayed volcanic dust, and marks the beginning of the eruptions from the vent in this neighbourhood, for above the reddish limestone lies a greenish tuff (2) with calcareous bands. Much of this band is concealed under the detritus of the beach, but it may be more than 12 feet thick. It is followed by a thin-bedded limestone (3) crowded with *Productus* and other fossils, about 3 feet thick, but swelling out to a much greater bulk further east. Next comes a group of green and red tuffs (4) with lenticular bands of limestone. Some of the tuffs are marked by bunches of coral in the position of growth. At the top of these tuffs a band of red ferruginous limestone (5) appears; it is thin-bedded, lenticular, and about 5 feet thick. It passes upward into about 15 feet of highly fossiliferous limestone (6). The quiet interval marked by the intercalation of this crowded mass of organic remains was brought to an end by a much more vigorous display of volcanic energy. The explosions began with the discharge of ashes, which in the section are now represented by from 12 to 14 feet of green tuff (7). The lapilli varied continually in size

(The Director
General and
Mr. Strahan.)

so that the tuff is made up of lenticular layers of fine and coarser material. The band, moreover, is much veined with calcite, no doubt derived from the solution of calcareous organisms either in the surrounding limestones or in the tuff itself. The top of this accumulation of pyroclastic material is marked by a thin red cherty layer (8), immediately above which lies the chief member of the volcanic group—a dull green amygdaloid of the usual basic character (9). This bed, perhaps 12 to 14 feet in thickness, has been a thoroughly vesicular scoriaceous basalt. It shows the “pillow” structure already referred to, some of the “pillows” being a yard or more in diameter. The vesicles, sometimes 4 inches long, have been filled with calcite. The upper surface of the sheet is rugged and scoriform, and the overlying sediments have filled up its hollows.

The outflow of this lava was followed by a much quieter phase of volcanic activity, when only occasional showers of dust were discharged over the floor of the sea on which the calcareous organisms had again spread. This portion of the record is contained in a band, about 9 feet thick, of lenticular seams of blue limestone (10), full of fossils, and divided by partings of fine tuff. A more prolonged and vigorous discharge of ashes is indicated by a band of green tuffs about 9 feet thick (11). The base of this band passes down into the ashy limestone group (10) below, so that there was obviously no interruption in the continuity of the volcanic phenomena. But the discharge of the ashes must have been sufficiently gentle or intermittent to allow of the continued presence of living organisms even on the bottom over which the volcanic detritus was accumulating, for the tuff contains lenticular seams and nodules of crinoidal limestone. In this band one of the characteristic features of Carboniferous tuffs already referred to is well displayed—the presence of abundant lapilli of a minutely vesicular basic pumice. A thin slice prepared from one of the calcareous bands was found under the microscope to be full of these lapilli and of various organisms, among which MR. NEWTON detected foraminifera (*Endothyra*?), and probably also echinoderms, corals, and entomostraca.

The gradual cessation of volcanic activity was marked by a return of the phase of sedimentation that had preceded the last more violent outbreak. The tuff-band just described passes upward into a red limestone (12) about three feet thick, banded with lenticular seams of green tuff like that underneath. Then comes a reddish nodular limestone (13), about three feet thick, with irregular partings of a ferruginous argillaceous material which may be highly decomposed volcanic detritus of the finest kind, marking some of the last efforts of the expiring volcano. Immediately above lies the ordinary well-bedded coarsely-crinoidal limestone of the district. Its lower seams include little blotches which may possibly also be decayed ashy material. But above this part of the section all trace of volcanic activity disappears, and the normal limestone, made up entirely of organic remains, resumes its place.

The next section of the volcanic group has been laid bare in a small bay three-quarters of a mile further to the east. Here again the rocks have been thrown into a highly inclined position, so that a considerable thickness of strata has been packed into a narrow strip of the beach. Short as is the interval between this outcrop and that just described, the succession of strata between the two places has entirely changed. The sheet of lava has disappeared, and a number of the tufts which towards the west are separated by layers of limestone here form more continuous deposits. But the whole volcanic group is thinner.

(The Director General and Mr. Strahan.)

At the base of the section the thick crinoidal limestone, with bunches of coral in the position of growth, passes upwards as before into reddish banded limestone with red clay partings, which no doubt represent much-decayed fine volcanic dust, for immediately above comes a deposit about 50 feet thick of green finely-bedded tuff. This band repeats the characters above described. It includes in its upper part a coarser layer, which encloses pieces of limestone, chert, and basalt, sometimes six inches long. It is marked also by the same evidence of contemporary organic growth and deposit, for at different platforms throughout its mass occur thin layers of ashy limestone and dark chert, while some of the finer portions of the tuff are nearly as fossiliferous as the ordinary limestone, being crowded with crinoidal joints, corals, bryozoa, brachiopods, &c.

Above this tuff lies a bed of hard, fine-grained, finely-laminated purple and grey sandstone, about two feet and a half in thickness, the most marked feature in which is the presence of numerous small cylindrical pencil-like bodies which descend from the upper surface of the band vertically across the lamination of the sediment. They may be worm-burrows. This arenaceous band seems to mark a pause of some duration during which volcanic activity was quiescent, and the calcareous organisms had not yet recovered their former place over this part of the sea-floor. Possibly this band may be paralleled with the lenticular limestones (No. 10) in the previous section.

Eruptions were renewed for the last time, when a quantity of ashes was discharged, now represented by a band of green and red tufts from five to seven feet thick. These materials may be continuous with the band No. 11 further west, like which their layers of coarser and finer material are mingled with much calcareous material. They are well banded, and in their upper part enclose rows of blocks of finely slaggy amygdaloid. Immediately above them comes a limestone 12 feet thick, which passes upward into some red, impure, decaying and probably ashy limestone, and this is followed by the great overlying mass of crinoidal limestone.

The most easterly of the three coast-sections lies 600 feet further along the shore. The upper part of the volcanic series is there cut out by a fault, which brings the tuff against the limestone. The calcareous bands in the tuff are here much thicker and more numerous than they are further west, and continue to

(The Director General and Mr. Strahan.) be crowded with organic remains. The volcanic material appears to be dying out in an easterly direction. Taking the whole evidence of this series of sections, we may reasonably conclude that in this instance also the eruptive vent lay somewhere to the west or north-west of the present shore-line.

The inland tract where contemporaneous volcanic rocks have been found in the Carboniferous Limestone lies on the ridge rather more than a mile to the north-east of Wrington. The ground has not yet been mapped in detail, but a traverse of it in different directions shows that a more careful examination of its rocks will entirely confirm the results obtained from a study of the shore-sections. Two outcrops (which may really belong to the same band) were noticed in Goblin Combe, one of them about 1,500 feet south from Warren House, the other about half a mile further to the south-east. At the latter place a group of tuffs is seen emerging from underneath a sheet of limestone. These tuffs consist of alternations of fine and coarser green and red volcanic dust and lapilli, with partings of limestone. They abound in the usual finely vesicular basic pumice. They are generally calcareous, and pass laterally and vertically into ashy limestone. The limestone-bands in turn are full of volcanic sediment, especially of lapilli of the green pumice. Some of these are partially oolitic, the oolitic grains being scattered through the ashy material.

At the lower or western outcrop blocks of a decaying basic amygdaloid are scattered over the surface. This rock, evidently a lava like those already described, must no doubt be in place close at hand. By following the detritus in mole-hills it is possible to trace its probable line of outcrop for some distance along the south side of the Combe. At the same place numerous pieces of ashy limestone and calcareous tuff may be picked up. These rocks are obviously also in place hereabouts, though their outcrop seems to be at present concealed. They resemble the strata seen half a mile up the valley. They must lie under the thick mass of fossiliferous limestone in which Cleve Combe has been excavated, and they probably overlies the limestone seen in Goblin Combe just above the tract where the volcanic detritus appears at the surface. Though the available evidence is defective, it is sufficient to prove the approximate position of another volcanic vent in the inland part of the Carboniferous Limestone, and to indicate that from this vent not only tuff but a sheet of vesicular lava was discharged over the floor of the sea.

A group of masses of igneous rock is shown on the Geological Survey Map (Sheet 19), rising along the ridge of Old Red Sandstone to the north of Shepton Mallet. These masses were also visited by the DIRECTOR GENERAL and MR. STRAHAN, with the view of ascertaining whether they formed part of the volcanic series which has now been described. But they were found to belong to a different petrographical series. Thin slices prepared from the freshest of the rocks in Moon's Hill quarry and from Beacon Hill have been examined by MR. TEALL, who finds that

they are undoubted andesites.* They appear to rise intrusively through the (Upper) Old Red Sandstone. They have none of the characters of true lavas, nor do they seem to have any accompaniment of tuff or agglomerate. Their age must remain undecided. They are presumably younger than the Old Red Sandstone, which in their immediate neighbourhood passes conformably upward into the shales and limestones at the base of the Carboniferous system. They may possibly belong to the Carboniferous volcanic series. Their more acid character than that of the lavas of Weston, Middle Hope, and Goblin Combe would not be a valid objection to such a relationship, for the intrusive sheets and bosses of the Carboniferous series in the south of Scotland and in Ireland are often much less basic than the contemporaneous lavas. This question, however, must remain until the district is surveyed in more detail. (The Director General and Mr. Strahan.)

South Wales Coal-field.

The re-survey of the Coal-field of South Wales and surrounding tracts has made steady progress during the past year, though the area surveyed would have been larger had it been practicable to retain MR. GIBSON in the district instead of temporarily transferring him to North Staffordshire. In the examination of the northern part of the area MR. CANTRILL continued his mapping of the Old Red Sandstone and Lower Carboniferous formations, while MR. STRAHAN and, for a short time in the autumn, MR. GIBSON carried on the survey of the Coal-measures. MR. TIDDEMAN, who was joined in the latter part of the year by MR. CANTRILL, was engaged upon the southern part of the coal-field and on the Secondary rocks which border it.

The following summary of the recent progress of the Coal-field work has been drawn up by MR. STRAHAN. It embraces the results arrived at by his colleagues and himself.

Carboniferous Limestone.—In carrying on the mapping of (Mr. Cantrill.) the Carboniferous Limestone westward in Brecknock, MR. CANTRILL finds that the Lower Limestone Shales keep their general character, but that the limestone at their base tends to dwindle away or to give place to shale. In Nant Byfre it is represented by a band of limestone eight feet thick which occurs sixteen feet above the base of the shales; westward of this stream no such rock has been recognised.

* MR. Teall's remarks on these rocks are as follows :—

E. 3195 (11), Beacon Hill.

Conspicuous phenocrysts of plagioclase and pseudomorphs, often a ferromagnesian constituent (augite or enstatite) in a felsitic matrix containing traces of felspar-microlites. The rock is too much altered for precise determination, but it undoubtedly belongs to the andesites.

E. 3197 (13), Moon's Hill Quarry.

A dark-coloured andesite composed of phenocrysts of plagioclase, augite and green serpentinous pseudomorphs after enstatite (?) in a microlitic groundmass.

(Mr. Cantrill) The main mass of the limestone, above this lower shaly subdivision, consists broadly of a lower division of dark limestone, in part oolitic; a middle mass of light-grey oolitic limestone; and an upper zone of dark limestones with abundant chert-nodules. A band (about three or four feet thick) rich in coral has been traced across the moorlands on either side of Glyn Tawe, at a height of 20 to 40 feet above the base of the main limestone. There are also bands of sandstone or grit with white quartz-pebbles in the main limestone, as on Pant Mawr and westward of Glyn Tawe, though their presence is seldom indicated by more than loose blocks. At the base of the light oolite there occurs a sandstone or sandy limestone, which weathers into an incoherent yellow sandstone. This band is 10 feet thick near the River Giedd, and is just reached in the bottoms of some of the quarries on Cribarth. Another grit-band 2 feet 6 inches thick is exposed in a quarry at Penwyllt at the top of the light oolite.

The upper limit of the dark cherty subdivision includes a thin limestone highly charged with quartz-grains and threads of sand. Above this band and immediately below the basal conglomerate of the Millstone Grit, some black shales with two or more thin bands of nearly black argillaceous limestones make their appearance at Careg Cadno and persist westward. The limestones are decalcified to a depth of from six to ten feet along the outcrop, and are dug out to that depth as "rottenstone" in a series of excavations which extends almost continuously from Penwyllt as far westward as the mapping has extended.

(Messrs.
Tiddeman
and Cantrill.)

The tracing of the Carboniferous Limestone in the Vale of Glamorgan, on the south side of the coal-field, has been continued by MESSRS. TIDDEMAN and CANTRILL. MR. TIDDEMAN finds that the central axis of the great Cardiff anticline ranges from Penllin, by Crackhill, passing thence two-thirds of a mile south of Ewenny Priory, and just north of Ogmores Castle. It next traverses the Merthyr Mawr Burrows, and passes due westward out to sea at Porthcawl. So much however is the limestone masked by patches of later rocks, that this line is by no means apparent without a careful study of the dips. Thus on the north side of the anticline the actual top of the formation can be fixed in one place only, viz., in the railway and tramway opposite Angelstown Asylum, while on the south side its underground extent beneath the newer rocks is unknown, except for some three or four inliers. Of these inliers, none of which had been previously detected, one is described by MR. TIDDEMAN as consisting of a narrow strip of limestone one mile long, brought up between two faults. It is well seen in the Vale of Glamorgan Railway, and is here and there covered with patches of conglomerate which are apparently of Liassic age, but are not easily distinguished from the Carboniferous Limestone. Another example occurs as a large inlier of erosion in the south-east end of Clemenston Park, where, as the limestone dips north, there may be reason to suspect the existence of another anticline south of the large one mentioned. A third inlier is exposed in a small quarry, also with a northerly dip,

half a mile W.N.W. of Wick. A fourth, which, however, is only (Messrs. Tiddeman and Cantrill.) doubtfully referred to a Carboniferous age, lies half a mile north of the last, and consists of tufaceous limestone with traces of conglomerate.

The Carboniferous Limestone of the Vale of Glamorgan is usually well-bedded, and grey to black in tint, varying to light-grey and drab-brown. White shelly limestone, such as is common in the north of England, is seldom seen, but fossils abound, especially in the lower beds, as at Penllin. Corals and large *Producti* occur in fine preservation, dotted over the bedding planes near Southerndown and Porthcawl. Oolitic structure is common, and occurs both high up and low down in the formation. The oolitic rock shown in the road between Southerndown and St. Brides Major is high up, while that exposed between Merthyr Mawr and Candleston occupies a much lower horizon. Another oolitic band of considerable thickness crosses Newton Downs, high in the limestone, but not at its top. A singularly cavernous bed, to a great extent filled up with chalcedonic silica, but containing also small crinoid joints, occurs near the base of the limestone at Penllin. Cherts are not uncommon, but are perhaps most abundant at the Witches' Point, Southerndown.

The Lower Limestone Shales have been recognised by Mr. Tiddeman at the centre of the anticline east of Penllin. They consist of shales with interbedded limestones dipping southwards beneath a scarp of the main limestone. Towards the north they are probably faulted, but westward yellowish and greenish shales and clays with decalcified crinoidal limestones or "rottenstones" are exposed for some distance. These strata have hitherto been mistaken for Rhætic shales.

MR. CANTRILL in examining the range of these rocks further east found that the bold east and west escarpment of limestone and shales of Bonvilston curves to the north-west and disappears near Welsh St. Donats under a plateau of what appears to be Lias concealed by Glacial Drift. It reappears around part of Stalling Down, where a thick band of purple oolite occurs at the base of the shales. At Llansannwr the shales contain several oolitic bands, the lowest of which is at least 25 feet thick.

Some lead-veins were formerly worked at St. Hilary in the main limestone, and a lode which is thought by MR. TIDDEMAN to form the northern boundary fault of the Lower Limestone Shales at Penllin has been tried for lead at Llangan.

Millstone Grit.—The lower part of this subdivision, composed (Messrs. Strahan and Cantrill.) of coarse quartz-grits loaded with pebbles of vein-quartz and irregularly split up by thin partings of dark shale, forms the barren moorland of Pant Mawr and the heights of Careg-gôch, Dysgwylfa and Careg-lem—large areas on which are entirely devoid of vegetation. It furnishes the purely siliceous sand from which the celebrated Dinas Fire Bricks are made, and is worked for that purpose at Penwyllt. Formerly these grits and some much crushed sandstones above them were worked on Cribarth also.

The shales which form the middle part of the Millstone Grit

(Messrs.
Strahan
and Cantrill.)

occupy a large part of the tract which separates the grit-scarps from the Coal Field, but are so thickly overspread with boulder-clay that no opportunities have occurred of investigating the fossiliferous limestones in them which have been described in previous *Annual Reports*.

The Farewell Rock, or uppermost sandstone of the series of sandstones and slates of which the higher portion of the Millstone Grit consists, presents no essential difference to the sandstones of the Coal Measures, and is not easily separable from them. The line, in fact, between these formations merely marks an arbitrary division useful for purposes of classification, but of no geological significance. The base of the Millstone Grit, on the other hand, indicates an abrupt change of original conditions of sedimentation over a large area, for not only were sand and pebbles spread abundantly over a region in which only limestone or fine sands had previously been accumulating, but a certain amount of erosion of the sediments already deposited took place. It is not impossible that the absence of the "rottenstone shales" east of Careg Cadno may be due in part to such erosion, but their persistence, when once they have appeared, makes it more probable that their present extension represents the limits up to which they originally reached.

This slight erosion of the top beds of the limestone is not to be confused with the subsequent dissolution of that rock which has sometimes proceeded on so great a scale, both in Monmouthshire and Glamorganshire, as to simulate an unconformity. Attention has been drawn in previous *Reports* to the lowering of masses of Millstone Grit by the removal of their limestone support, and in the district examined last year MR. CANTRILL finds that there are several small patches of Millstone Grit on the west of the Tawe lying as much as 100 feet below the level of the main grit escarpment. The bedding is but little disturbed, and the masses rest on the "rottenstone shales," showing that their position is not due to contemporaneous erosion of the top beds of limestone. They are thought by MR. CANTRILL to have moved slowly down and away from the parent bed after the fashion of a landslip.

(Messrs.
Strahan and
Gibson.)

Coal-measures.—The equivalents of the Steam Coals of the Rhondda Valleys have now been traced by MR. STRAHAN and MR. GIBSON westward along the north crop as far as Ystradgynlais. They include in descending order the Red, the Stwrain, and the White Veins, which have been worked to a small extent here and there, and below these the Four Feet, the Eighteen Feet, the Nine Feet or Big, and the Brass or Yard Veins, all of which have been, or are being, extensively worked. The Eighteen Feet and Nine Feet Veins correspond to the Six Feet and Nine Feet of Aberdare, but in the ground last surveyed they have changed from the condition of steam-coals into that of true anthracitic coals, after passing through an intermediate stage in the Vale of Neath.

The base of the Coal-measures is not easily identified owing to the poor development of the Farewell Rock. The Cnapiog coal, however, which is the lowest seam in the Vale of Neath and at

Hirwain, can be recognised in the Vale of Swansea also, and the base-line has been drawn, as in those districts, so as to include this seam and some shales below it in the Coal-measures. A considerable thickness of barren measures which form the Mynydd y Drum separate the Stwrain from the Red Vein, but the Red Vein is followed at no great distance by the Welsh Vein, the Pinchin, the Ynysarwed, and the Pen-y-graig. Of these the Ynysarwed is regarded as the representative of No. 2 Rhondda, and the Pen-y-graig of No. 1 Rhondda, a view which is borne out by the fact that the Ynysarwed lies at the foot of a crag of grit and marks the oncoming of the great mass of Pennant sandstone. It is noticeable also that a band of conglomerate, containing lumps of ironstone and pebbles of quartz in a coarse grit matrix, lies a few feet above the coal, a feature which has frequently been observed in the roof of No. 2 Rhondda elsewhere. The Ynysarwed coal is about 2 feet 10 inches thick, and is being worked at Crynant and Resolven as a steam-coal. (Messrs. Strahan and Gibson.)

The measures above No. 2 Rhondda continue to show that change which has been referred to in former *Annual Reports* as taking place westward. Though chiefly composed of massive grits in the lower part, they contain many bands of shale with thin seams of coal in the upper part. The coals also tend to become more important westwards, and have been largely worked in the Neath and Swansea neighbourhoods. The re-survey of this tract having been only begun, it would be premature to attempt a precise correlation, but so far as the evidence yet collected goes the seams appear to correspond to the Llantwit group, the lowest of them being the Graigola, which becomes the Wenallt, the Bettws Four Feet of the Llynfi and Garw Valleys, and the Ty-du Vein of Llandyfodwg and Ton-yr-efail. The Ty-du Vein is probably the Pen-y-groes Vein, which lies about 60 yards below Llantwit No. 3 in the Llantwit basin. Whether any representative of the Mynyddislwyn Vein or Llantwit No. 1 exists at Neath or Swansea cannot yet be stated.

These measures lie in a deep syncline which runs east and west across the Vales of Neath and Swansea, and is traversed by a succession of large north and south faults. Though rising gently northwards to the north crop, they turn up abruptly towards the south, and the massive grits of the lower part of the Pennant emerge along the north side of Swansea Bay with inclinations of 40° and 50°, forming a conspicuous range of hills between Baglan and Swansea. At their base there occur three seams of coal, about ten yards apart, which have been worked on the east side of Briton Ferry under the names of the Tor-mynydd, Jonah, and White Veins. The Tor-mynydd Vein corresponds in position to the Ynysarwed of the north crop and to the Rock Fawr of the south crop, and therefore represents No. 2 Rhondda. This identification affords a clue to the position of the lower productive measures in the foreshore, where they have not yet been proved, but it should be remembered that the Moel Gilan Fault, where last seen near Baglan, ranges in a westerly direction across Swansea Bay, and that it is accompanied

(Messrs.
Strahan and
Gibson.)

by much disturbance of the strata, especially on its northern or upthrow side.

The disturbance alluded to takes the form of somewhat sharp folding, such as is seen in the sides of the Cwm Avan Valley. It may be noticed, however, that the plication is generally confined to such plastic strata as compose the infra-Pennant series, the massive Pennant grits themselves showing but little disturbance. A good example of the different effects produced by compression on the two rocks is furnished along the Vale of Neath Disturbance, where the Pennant escarpment exhibits a gentle and uniform dip, though the soft measures below it are thrown into sharp folds. Explorations are now showing that the lower measures are too much crushed and broken over considerable tracts near the head of the Rhondda Valleys for their coals to be workable, though the Pennant rock overlying them is unbroken, a fact which emphasises the importance of tracing out such lines of crush as those of the Vale of Neath and Cribarth in the greatest detail.

The anthracitisation of the coals which has been alluded to in former *Annual Reports* proceeds steadily in a direction somewhat west of north. The lower seams of the north crop in the Vale of Swansea are true anthracites, while the Ynysarwed Vein or No. 2 Rhondda becomes a steam-coal at Resolven, and is intermediate between a steam-coal and an anthracite at Crynant. Of the Neath veins the Wernfraith alone is a house-coal, all the others being steam-coals, though they correspond to the Llantwit group, the most noted house-coals of the coal-field. No connection has appeared between the anthracitisation and the faulting, but the change seems rather to be a form of regional metamorphism dependent upon the temperature to which any part of the coal-field has been subjected during depression, as was suggested many years ago by DE LA BECHE. More precise information than we at present possess as to the changes undergone by any one seam, and as to the direction of maximum change, is highly desirable.

A few fossiliferous horizons have been noted in the Coal-measures. The shales above No. 1 Rhondda in Resolven Mountain have been found by MR. GIBSON to contain slightly calcareous ironstone nodules, in which entomostraca of the genus *Carbonia* are associated with *Anthracomya*. Black shales with entomostraca have been noted by him also beneath a coal that may represent No. 3 Rhondda, 250 feet below the Ynysarwed Vein or No. 2 Rhondda. MR. HOWEL, of Bryn Coch, has furnished specimens of *Levia* and *Anthracomya*, with the remark that they abound in the shales associated with the Graigola seam near Neath.

(Mr. Strahan.)

Faults and Disturbances.—In the *Summary of Progress* for 1897 the course of the Vale of Neath Disturbance was traced, and mention was made of a parallel line of fold of which evidence had been obtained seven miles to the north-west. These two great lines of crush have now been more fully worked out, and their general similarity as well as parallelism have become

strikingly evident. Both may be described as narrow belts of (Mr. Strahan.) contorted strata, the contortion occasionally passing into fracture and even overthrust, as at Dinas Rock. Though accompanied by some normal faulting, they are not comparable in any respect with the clean-cut normal N.N.W. faults which form so conspicuous a feature in the structure of the coal-field, but have evidently resulted from compression brought about by a force acting from the north-west. That they afforded relief is clear from the undisturbed condition of the strata on either side of and between them. (See Plate II.)

At its point of entry into the coal-field the Vale of Neath Disturbance consists of a series of sharp flexures, the net result of which is a downthrow to the north-west of about 200 yards, for at Glyn Neath the top of the Millstone Grit of the southern side of the valley would, if projected, pass that distance above the top on the northern side. Further west, however, as subsequently explained, the downthrow is in the opposite direction, for the Ynysarwed (No. 2 Rhondda) and other seams crop out about two miles further north on the south side than on the north side of the valley, an effect which would be brought about by a vertical downthrow to the south-east of about 250 yards. Here again, however, the displacement is probably due to a number of folds rather than to a clean fracture, but the disturbed belt coincides with and is everywhere hidden by the alluvial flat of the Neath. This is the last definite evidence obtained of the existence of the disturbance; it probably dies away a short distance to the south-west, for no trace of it exists at Briton Ferry.

The parallel line of disturbance alluded to may conveniently be named after Cribarth, a conspicuous anticlinal ridge of limestone flanked by Millstone Grit. The disturbance enters the area undergoing revision in Glyn Senni, and runs thence to the Tawe Valley through ground surveyed by MR. CANTRILL. It was found by him to traverse a depression between Fans Fraith and Gihirych as a faulted syncline, the effect of which was to repeat in Fan Gihirych the hard red sandstones which form Fan Fraith, at the same time that it introduced a small outlier of "grey grits" and limestone in the depression. It is, therefore, a downthrow to the north-west. The disturbance can be traced thence by high dips towards the Tawe Valley, which it enters to the north of Penwyllt. Here it consists of a strong anticline crossing under Craig-y-Nôs Castle and forming the crest of Cribarth, with an equally marked syncline on its north side, while a syncline in the Tawyneu Valley and an anticline in Cefn Cûl are also probably connected with it.

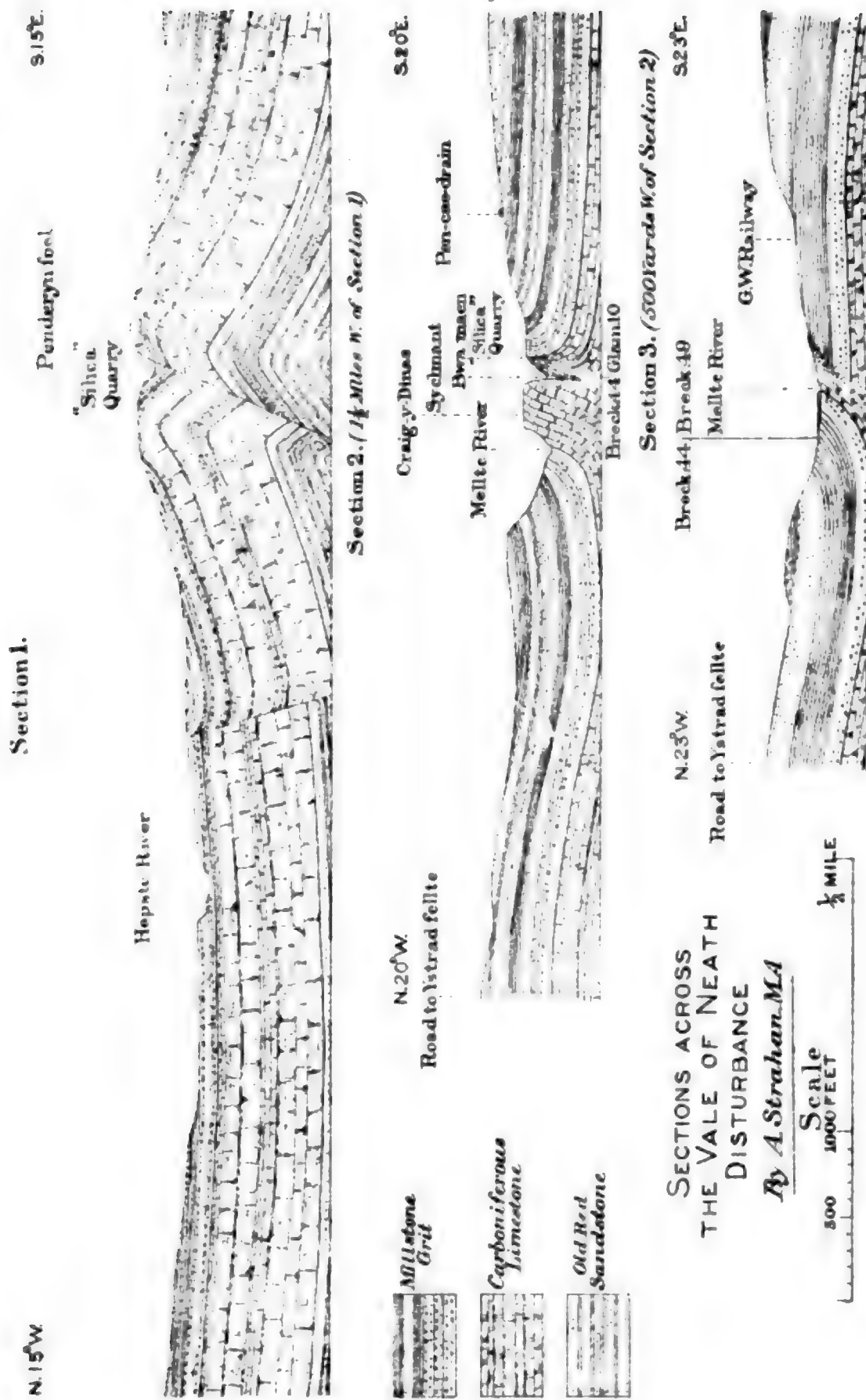
The crags and rocky sides of Cribarth afford a perfect dissection of the disturbed belt, and show that it consists there of a series of sharp synclines and anticlines. They enable us also to see that though the disturbance as a whole keeps its character for some miles, yet the individual folds composing it rarely run more than half a mile, the principal anticline of Cribarth alone excepted, which continues for not less than three miles. The

(Mr. Strahan.) anticlines and synclines therefore may be more correctly described as elongated domes and basins respectively, rapidly giving place to one another, and crowded into a belt of about a mile in width. The disturbance, as a whole, has at present been traced for a distance of about ten miles in a general direction W. 35° S.

The fact that these two great lines of disturbance run nearly at right angles to the north and south system of faulting, but in a direction not widely different to that of the pre-Triassic folding of South Glamorganshire, suggested that they also may belong to the earlier age, and this inference seemed confirmed by the fact that in one case at least the anticlinal axis was distinctly shifted by a north and south fault, as subsequently described. On the other hand, this year's work has made certain what was only suspected before, that some powerful faults of the north and south system run up to the Vale of Neath Disturbance and lose themselves in it. A notable example is that of the Pen Castell Fault, a large downthrow to the west, which has been traced by Mr. GIBSON from the south into the disturbed belt near Resolven, but which does not emerge on the north. Still more significant is the behaviour of the Glyn Corrwg Fault, a great westerly downthrow, which runs into the disturbance from the south and turns at right angles to follow it westward. The proof of this structure lies in the fact that the Vale of Neath Disturbance is a downthrow to the north down to its intersection by the fault, but that at that intersection it suddenly becomes a downthrow in the opposite direction. It is evident therefore that the strata in the angle formed by the fault on the east and the disturbance on the north have dropped.

Another fact which may throw light on the age of the two disturbances is that both have obviously influenced the direction of the river-system. The Neath below the confluence of its five principal tributaries follows the one rigidly; the Tawe, though it crosses the other, turns immediately to run parallel with it. In this the Vale of Neath and Cribarth Disturbances differ both from the north and south system of faulting, and from the pre-Triassic east and west folding, neither of which has had any share in determining the directions of the rivers.

The three sections forming Plate II. have been drawn to illustrate the points mentioned above. Section 1 is taken through the great excavation on Penderyn Foel, where crushed Millstone Grit has been dug for the manufacture of fire-bricks. The highly inclined grits and the normal fault are fully exposed in the pit, as depicted in the section, while the faulted syncline shown further north is readily traced in and along the south side of the Hepste. Section 2, one and a half miles west of Section 1, shows that the fault has passed into a belt of broken limestone intersected by an infinite number of veins of calspar, this crush-rock forming the bed of the Sychnant. The syncline to the north is still recognisable, while the main antieline has gained intensity, and admirably expresses the compression to which the whole structure is due. In the Bwa Maen, or Bowstone, the folding



Wyman & Sons, Lith 3784 3. 99.

of the limestone has about reached its limit of possible sharpness. (Mr. Strahan.) In Section 3, 500 yards further west, that limit has been passed, and the limestone of the north side has not only broken away from that of the south, but has been pushed over both it and some of the overlying Millstone Grit. Here relief from the strain was obtained by overthrusting, and sharp folding became no longer necessary. The sections illustrate the development of an overthrust from a broken anticline.

Of the north and south faults traced last year the principal are the following:—

The Henryd Fault, which causes the fine waterfall of that name, by throwing Coal-measure shales down on the west against Farewell Rock on the east. Its course northwards is clearly marked to Penwyllt, where it cuts across and shifts the crest of the Cribarth anticline; southward it enters the Coal-measures near Capel Colbren and dies out.

The Glyn Corrwg Fault has been traced into the Vale of Neath at Blaen Gwrach by MR. GIBSON. It is commonly identified with a westerly downthrow of 40 yards which runs west of the Aberpergwm workings, and has been proved on the east of Onllwyn. The two faults are nearly in a line, but their identification by the miners was wholly conjectural.

The Pwllau-bach Fault has been traced from the Vale of Neath near Pentre Clwydau across Hir Fynydd to Bryn-y-Garn. Thence it runs between Onllwyn and Seven Sisters, on the east of Abercraf Colliery, and serves to account for the termination of the outcrop of pebbly grit which forms so marked a feature on the southern slopes of Cribarth. It cannot, however, be found either to the north of the Cribarth Disturbance or to the south of that of the Vale of Neath, though its throw near Onllwyn, between the two, amounts to 80 yards down to the west.

The Pen Castell Fault has already been mentioned. It would, if it kept its course across the Vale of Neath, pass near Blaen Nantyr-Hebog, where, however, the continuous crop of the Ynysarwed Vein shows that there is no fault.

The Crynant Fault is a downthrow to the west which may be traced from the Vale of Neath across the mountain, and has been intersected in the mouth of Crynant Level. It is believed to be the Wern Plemys Fault of Swansea Vale, which has a throw of 21 yards, but it seems likely to be upwards of 60 yards at Sarn Helen, by the identification of the coal-crops on either side of it.

The Ynys-geinon Fault has been proved at the colliery of that name in Swansea Vale to be a downthrow to the west of 56 yards. Its course southwards has not yet been determined.

A number of large north and south faults near Neath and Briton Ferry were undergoing investigation at the close of the year, and will be described in next year's *Report*.

Two well-marked post-Liassic faults have been traced in the neighbourhood of Cowbridge by MR. CANTRILL. They run in a general west-south-westerly direction, one of them south of St. Hilary with a downthrow to the south, and the other, with a downthrow to the north, by Pendoylan, Welsh St. Donats, Aberthin, Cowbridge, and along the north side of Llanbleiddian Hill.

Witches' Point, at Dunraven, is a promontory of Carboniferous Limestone, capped by Lias, and owes its existence to a large reversed post-Liassic fault running in a northerly direction. The fault is admirably exposed in the cliff.

Leicestershire and Derbyshire.

(Mr. C. Fox-Strangways.) The field-work in the Leicestershire and South Derbyshire Coal-field having been completed in 1897, MR. FOX-STRANGWAYS was last year occupied in carrying on the survey to the north and east so as to complete the mapping of the surrounding ground, which will be included in a special map of the coal-field. In this manner all the area to the south of the Trent and west of the Soar has been finished. The rocks comprised within this district are Carboniferous Limestone, Millstone Grit, Permian, Bunter, Waterstones, and Keuper Marl, with a certain amount of Drift, principally on the eastern side.

The re-survey of these rocks has necessitated very considerable modifications of the old boundary-lines. The Carboniferous Limestone and the Millstone Grit remain indeed mainly as shown on the published map, but a rather larger exposure of the former has been found at Calke Abbey than is shown on that map, while a fine cliff of the limestone in the private grounds had been coloured as part of the Millstone Grit.

When MR. FOX-STRANGWAYS first commenced the revision of this ground, he thought that the different beds of grit might be traced out separately, but he afterwards found them not to be sufficiently marked in this highly cultivated district to admit of being mapped satisfactorily. Some of the stronger beds which may be traced for a certain distance help to show the general run of the strata.

Staffordshire.

The resignation of MR. DE RANCE already referred to, rendered necessary some re-distribution of the staff, in order to push forward the re-survey of the North Staffordshire coal-field and the surrounding tracts. Accordingly MR. WALCOT GIBSON was moved from Wales to undertake the continuation of the mapping of the Coal-measures. MR. WEDD, on his appointment last spring, was placed among the so-called Permian rocks on the west side of the coal-field. In the autumn, after quitting his field-work in the Highlands, MR. GEORGE BARROW was requested to revise the older Carboniferous rocks which emerge from under the coal-field on its eastern side, while MR. LAMPLUGH during the autumn undertook the examination of the red rocks along the southern border of the district. The general supervision of the whole field-work of the region was entrusted to MR. FOX-STRANGWAYS.

Yoredale
series and
Millstone
Grit.

(Mr. George
Barrow.)

Among the Carboniferous rocks lying to the east of the coal-field MR. BARROW has made considerable progress in the re-mapping. These rocks belong to the Yoredale series and Millstone Grit, but include also a portion of the Lower Coal-measures. They essentially consist of dark shales associated with variable coloured marls. The shales generally contain plant-remains, but they are throughout marked by the occasional occurrence of

indurated and remarkably persistent bands, which are often crowded with marine organisms. These bands are frequently underlain by seams of coal, but, in the area surveyed last year they are too thin to be worked, and in some cases are merely a kind of smut.

Yoredale series and Millstone Grit.
(Mr. George Barrow.)

The shales are further characterised by the presence of a number of sandy beds, of which two specially coarse grits, lying below the Coal-measures, are known as the *First* and *Third Grits*. Some distance below these, the first group of the fine hard sandstones that distinguish the lower shales as a whole are often quarried for road-metal. Fine as these bands generally are, it is not uncommon to find in them seams an inch or two thick composed of pebbles and coarse sandy material. Still lower in the series of shales comes a grit that varies greatly both in thickness and coarseness. It is made up of grit-lenticles with irregular marly partings. MR. BARROW believes that it undoubtedly represents the Yoredale Grit of the area to the north, which PROFESSOR GREEN included in the Millstone Grit. The base-line for the Millstone Grit has been drawn at a much higher level near Stoke than in the district further north; this difference being due to the rapid thinning away and splitting of the gritty strata as they advance southwards.

A great thickness of shales, as the persistent high dips show, underlies this group of grit-wedges, and passes down into an alternation of thin fine sandstones and shales, beneath which come the impure limestones and dark shales that overlie the main mass of the Derbyshire Limestone. Even in the lowest fine sandstones, however, careful examination shows the presence at times of lines and pockets of pebbles, suggesting that they represent the dying-out southward of the Millstone Grit rather than any part of the true Yoredale series, which the so-called Yoredale series of this district does not in the least resemble. Whatever may prove to be the true age of this great mass of shales with the fine hard sandstones, it certainly seems desirable not to apply to them the term Yoredale, as has also been found advisable in the north of England. The hard shale-bands with their marine organisms will almost certainly enable us eventually to determine whether these shales are not really replaced by grits of Millstone Grit age to the north, so that the question can be left over to be decided by the results of the revision of the ground on the large scale maps.

The Carboniferous rocks had been greatly disturbed and faulted in the area between Stoke and the Churnet Valley before the deposition of the Bunter formation. One of the most remarkable features in the district is the existence of what may be termed pseudo-escarpments. Standing on the edge of the Millstone Grit we invariably look down on a valley composed of the higher Coal-measures no matter what may be the dimensions of the valley. So persistent is this feature as to convey the general impression that we are looking at a series of ordinary escarpments with lower and *not higher* beds rising up from beneath them. The singular arrangement here referred to

Yoredale
series and
Millstone
Grit.
(Mr. George
Barrow.)

is repeated on a finer scale in the outcrop of the great mass of limestone to the east. In almost all cases the Millstone Grit and the Limestone rise from the low-ground with a high dip, which often becomes nearly vertical and in some few cases is actually inverted. But at the top of each pseudo-escarpment the dip almost invariably flattens and is often quite low at less than 200 yards from the "edge," as this feature is often called, and is so often perpetuated in village-names such as Brown Edge, Baddeley Edge, etc.

The same singular topographical detail is to be found in Northumberland, where in almost any quarry in the Great Limestone, while the shales and sandstones are quite horizontal along the strike face, the limestone is almost always more or less violently contorted. The explanation may be that when the district was subjected to the "compression" movements that compacted the muds and sands into shales and sandstones the limestone, which is peculiarly dense, was possibly more incompressible and "buckled-up" everywhere, as the only means of enabling it to occupy a smaller space. In the Staffordshire area the grit and limestone were both deposited upon a considerable thickness of soft mud, which could be squeezed into a smaller space than the grit and still smaller than the limestone. The height of the pseudo-escarpment gives an index of the difference in compressibility of the different varieties of material. As the evidence from Northumberland would lead us to expect, the limestone, being least compressible, has given rise to higher pseudo-escarpments.

Coal-
measures.
(Mr. Gibson.)

The coal-field mapping by MR. WALCOT GIBSON has led to results of considerable scientific interest, and some of which promise to be of economic importance in regard to the future development of the coal-mining industry of the region.

The Upper Coal-measures cover a wide area west of Burslem and Longton and attain there a great development. By means of the detailed surveying with maps on the scale of six inches to a mile it has been possible to subdivide this great thickness of strata into four groups which are markedly constant in lithological characters. They are distinguished by the presence of zones of limestones and shales, rich in entomostraca, which have been found to be of considerable stratigraphical value. Though seldom exceeding a foot in thickness, the entomostracan limestones are persistently developed. Some zones, consisting only of an inch or two of shale or limestone, but frequently crowded with entomostraca belonging to the genus *Carbonia*, have been traced along the strike for considerable distances. These zones have served as useful datum-lines in determining the position of some thin coals towards the base of the series, besides materially assisting in tracing the main dislocations of the district, and in showing the great probability of the existence of Upper Coal-measures at the surface to the west of the North Staffordshire anticline.

The strata are well exhibited in numerous marl-pits, quarries, road-and railway-cuttings and stream-courses, west of the Pottery

towns of Burslem, Hanley, Stoke-upon-Trent, and Longton. The best sections of the Upper Measures in the Midland Counties are to be found in this district. So far as the revision has proceeded, the following stratigraphical divisions in descending order have been recognised :—

- | | |
|--|---|
| (4) <i>Keele Sandstone Series</i> | Red sandstones and marls, calcareous breccias, fossiliferous (entomostracan) limestones. The base is a black shale crowded with the remains of <i>Entomostraca</i> , while some red marls above contain numerous plants of Coal-measure species. Thickness exceeding 700 feet, but summit nowhere seen. |
| (3) <i>Newcastle-under-Lyme Series</i> | Grey sandstones, marls and shales, with four thin coals. Two bands of fossiliferous limestone (<i>Entomostraca</i> , <i>Anthracomya</i> , fish-remains) form the base. Thickness 250-300 feet. |
| (2) <i>Etruria Marl Series</i> ... | Red and mottled marls with thin bands of coarse green grits near the summit and base. A <i>Spirorbis</i> -limestone occurs 80 feet below the summit at Chesterton. Thickness 700-900 feet. |
| (1) <i>Black Band Series</i> ... | Grey and mottled marls, the grey marl predominating. Bands of ironstone with <i>Entomostraca</i> , <i>Anthracosia</i> (<i>Carbonicola</i>), fish-remains. Occasional bands of grit sometimes 30 feet thick. Several thin coals. Numerous zones of limestone and shales with <i>Entomostraca</i> ; a band of limestone, constant in position (36-40 feet) above the Bassey Mine Ironstone, forms the base. Thickness about 250 feet. |

The base of this great thickness of conformable measures is taken at the first limestone above the Bassey Mine Ironstone, a divisional line which has been already proposed by MR. WARD.*

In taking the Bassey Mine Limestone, as it is generally known in the district, and those at the base of the other groups as divisional lines, it must be remembered that, for the present at least, they are strictly lines of convenience. As no stratigraphical break has yet been ascertained in the entire Coal-measure series of North Staffordshire, it is necessary to fall back on arbitrary lines for dividing up the strata, and for this purpose these limestone-bands are most useful. As the work advances, it may be found necessary to include in the Upper Coal-measure, beds lower down in the system. All that is claimed for the divisions in the table here given is, that the different groups thus discriminated can be recognised over the whole area and can be satisfactorily laid down on the map.

Owing to the valuable nature of the Bassey Mine Ironstone and the marls above and below, numerous marl-pits from Longton to Burslem have been opened, so that the crop of the lowest limestone can be readily traced. For the sake of comparison these marl-pits have been measured foot by foot, and sections have been plotted on a uniform scale. Some slight lithological and palæontological grounds exist for taking the Bassey Mine Limestone as a dividing-line from the beds below. Above this

* JOHN WARD, "The Geological Features of the North Staffordshire Coal Fields." *Trans. North Staff. Inst. Min. and Mec. Eng.*, vol. x. p. 26, 1890.

Coal-
measures.
(Mr. Gibson.)

limestone no workable coals occur, these being confined to the Middle and Lower divisions adopted for North Staffordshire. The Middle division is the chief repository of the ironstones and Pottery coals, the Lower division contains the best and thickest bituminous coals. The fauna above the limestone and that of the limestone itself are essentially estuarine or fresh water throughout, while marine beds occur in the Middle and Lower divisions. MR. KIDSTON* also states that the flora above the Bassey Mine Limestone is different as a whole from that below it.

Below the Bassey Mine Ironstone come the Little Row Coal and Peacock Coal. The grey marls above the Bassey Mine and Peacock Coals are locally known as the Bassey Mine and Peacock marls. The marls are extensively used in the district in the manufacture of saggers, stilts, bricks, &c.

(1) The limestone above the Bassey Mine Ironstone is very persistently developed at a uniform distance of 36 to 40 feet above the ironstone. It is a light grey or blue limestone, rich in *Entomostraca*. *Spirorbis* is fairly common, while fish-teeth and scales are also present. Resting on the limestone are three to four inches of red, grey, or black shales, containing abundant remains of *Entomostraca* associated with *Anthracomya* sp. In the marl-pits at Sneyd Green and Burslem a black calcareous shale averaging one foot in thickness and largely made up of *Entomostraca* is exposed. It is constant in its position at forty feet above the Bassey Mine Limestone, the intervening measures consisting of grey nodular marls with occasional lenticular bands of yellow grit.

In the marl-pits near Burslem several thin bands of grit, lying in grey marls, come in about fifteen feet above this black shale. The bands are seldom more than two inches thick. Some are apparently barren of fossils, others contain plant-remains, while two or more bands contain entomostracan remains associated with a small form of shell as yet undetermined. The presence of this curious little fossil on this horizon is interesting, as a similar form is abundant in some red and grey measures at Western Sprink, certainly as low down as the lower part of the Middle division of the productive measures of the district. Associated with it at Western Sprink is *Lingula*. Above these fossiliferous grits some red and grey measures, and thin entomostracan shales, are well exposed in the marl-pits at Longton, Fenton Low, Hamptons, Cannon Street, and Ladyswell. In Hamptons, Ladyswell and Cannon Street marl-pits a thin band not exceeding four inches thick of a black shale with *Entomostraca* lies a few feet above a three-foot coal. In all these pits the beds between the coal and fossiliferous shale consist of red mottled marls. It is a noticeable fact that throughout the Upper Measures of North Staffordshire the *Entomostraca* are found in strata that overlie a set of red beds or lie in the midst of red rocks, as if the presence of ferruginous solutions had been essential to the full life of these minute crustaceans.

* R. KIDSTON, "Additional records and notes on the Fossil Flora of the Potteries Coal Field." *Trans. Roy. Soc. Edin.*, 1897.

Thirty feet above the shale in the Ladyswell and Cannon Street marl-pits a shaly ironstone containing *Anthracomya Phillipsii* is overlain by a massive grit. Very much the same section is exposed in the Longton Hall marl-pit, where, however, the three inches of shale are replaced by a four-inch band of grey limestone with *Carbonia* and fish remains. How far the measures just described correspond with the Black Band series of the Silverdale district remains to be ascertained, but they appear to lie on the same horizon.

(2) The Black Band series graduates upwards into a great thickness of red, mottled, and ochreous marls with occasional bands of coarse grit and conglomerate. The grit bands are thickest and most frequently present towards the summit and base of the series. It is proposed to name these strata the Etruria Marl series, from their being extensively excavated at Etruria. From Cocknage on the south they are exposed in an almost continuous line of pits to Chesterton on the north, a distance of 8 miles. Large marl-pits have also been excavated in the Silverdale and Madeley Heath districts. The marls are used for bricks and drainpipes. In the Heath brick-pits at Chesterton, thirty feet of grey sandstone with a shaly ironstone and thin coal below it are overlain and underlain by red marls belonging to the Etruria series. The ironstone is made up of laminæ, containing numerous flattened specimens of *Anthracomya Phillipsii*. In the Metallic brick-pits at Chesterton a thin nodular band of red, marly limestone, containing large specimens of *Spirorbis*, occurs about 70 feet below the summit of the series in a thick deposit of red marl. This is the only locality in which a fossiliferous band has been found in the Etruria marls.

(3.) The next series in ascending order consists of grey sandstone, marls and shales, with four thin coals. Two of these coals towards the base are found over the whole district. The base is drawn at the horizon of two bands of limestone, which have been found to be constant in position beneath these two coals. As this subdivision of the measures is well exposed in the railway-cutting at Newcastle-under-Lyme, it is proposed to call it the Newcastle-under-Lyme series. It possesses very constant lithological characters, and is easily recognised from its position between two sets of red measures (the Keele series above and the Etruria marls below).

The limestone and fossiliferous shale at the base are invariably present. The following section, seen in the marl-pits near Longport Station, gives the characteristics of this part of the series:—

	Ft.	In.
Yellow flags and shales	20	0
Yellow shales (fish-remains)	0	6
Red shales (<i>Carbonia</i>)	1	6
Black shales (<i>Carbonia</i> , fish-remains)	2	0
Red limestone (<i>Carbonia</i> , fish-remains)	1	0
Yellow shale	0	8
Blue limestone (<i>Carbonia</i> , <i>Anthracomya</i>)	1	0
Yellow shale	1	0
Purple marls (Etruria series)	30	+

Coal-
measures.
(Mr. Gibson.)

The specimens of *Anthracomya* in the blue limestone are small in size but admirably preserved. In the red shales associated with the limestone in the road-cutting from Trentham to Whitmore, PROF. RUPERT JONES recognises *Estheria tenella* and *Carbonia salteriana*. It is believed that the Newcastle series will play an important part in future boring operations by leading to the recognition of the presence of Upper Coal-measures beneath the red rocks that conceal the Coal-measures on the west and south of the coal-field.

(4) The Newcastle series graduates upwards into a considerable thickness of red sandstones, marls, and occasional cornstone, which are well seen in quarries, railway-cuttings, and natural exposures around Keele. Hence, these strata may be conveniently distinguished as the Keele series. The area occupied by them is coloured as Permian on the published Geological Survey Map (Old Series). The fact of their strict conformability to undoubted Upper Coal-measures has been mentioned in the *Summary of Progress* for 1897 (p. 109). Fresh evidence was obtained last year to prove their intimate connection with the Upper Coal-measures, and it is a question for further investigation how far these red measures should be grouped with the Upper Coal-measures or taken as representatives of the Supra-Carboniferous rocks of Continental geologists. They certainly cannot be classed with the Permian formations of Lancashire and the N.E. Counties.

In the Newstead boring, where 550 feet of red measures consisting of alternations of red micaceous sandstones and red marls, overlying the Newcastle series, were pierced, the base is provisionally taken at a black and red shale (with *Carbonia*, Fish-teeth, *Pelecypoda*), which has not been met with at the surface of the ground, though the red sandstone with cornstone bands, a few feet above, is seen in many sections. The railway-cutting near Keele Park Station exposes a good section of red sandstones and marls, in the midst of which lies a band of black limestone one foot thick, which has yielded specimens of *Carbonia* and *Spirorbis*. In Dunge Wood a cream-coloured limestone, with *Carbonia* and *Anthracomya*, is associated with red marls and sandstones, but the ground is here traversed by faults, and this limestone may be the seam that is found at the base of the Newcastle series.

West of Madeley and Ashley MR. WEDD finds these red measures coming to the surface from under the Trias in the Willoughbridge and Mucklestone districts, where they consist of dark-brown and pink-brown, fine-grained felspathic sandstones. Marls are there seldom seen, but the same observer thinks it probable that red marls occupy some of the gently sloping ground. Near Willoughbridge he has come upon a dark limestone with *Carbonia* associated with crimson marl that has been formed from the weathering of a red felspathic sandstone. While he regards this limestone as undoubtedly in place, he has also found blocks of a hard crystalline and greyish buff limestone lying on the floor of a disused quarry near Sidway Hall, east of Willoughbridge, which no doubt have come from a seam that was dug out

of the pit, though not now visible. No organisms were found in the blocks. Coal-measures. (Mr. Gibson.)

The red colour of the Keele series is no doubt original. Throughout the entire Coal-measure period, over what is now the area of North Staffordshire, red deposits were being laid down at intervals. The red marls and limestones of Western Sprink and the red sandstone above the Ten-foot coal are scarcely distinguishable from those in the Keele series.

In Spring Valley, Trentham Park, a breccia is exposed which is made up of small angular fragments of Carboniferous Limestone in a red matrix. It is unconformably overlain by Pebblebeds of Bunter age. The field-work last year was not carried far enough to determine the horizon on which this breccia lies.

An interesting specimen of an iron-ore was discovered by Mr. GIBSON towards the close of the season in the Fenton Park Clay Pits. It is a greyish ore, occurring in bands and nodules in grey marl. An analysis by DR. POLLARD shows:—

(E. 3214.)

FeO	-	-	-	-	-	49.40
Fe ₂ O ₃	-	-	-	-	-	.08
Al ₂ O ₃	-	-	-	-	-	1.56
P ₂ O ₅	-	-	-	-	-	.24
MnO	-	-	-	-	-	.82
NiO	-	-	-	-	-	trace?
CoO	-	-	-	-	-	trace?
CaO	-	-	-	-	-	.85
MgO	-	-	-	-	-	1.36
CO ₂	-	-	-	-	-	31.87
S	-	-	-	-	-	trace (as FeS ₂).
Organic matter	-	-	-	-	-	.47
Residue ignited	-	-	-	-	-	11.68
Water at 105°	-	-	-	-	-	.23
Water on ignition	-	-	-	-	-	1.20
						99.76
Ignited insoluble residue :						
SiO ₂	-	-	-	-	-	7.22
Al ₂ O ₃	-	-	-	-	-	4.00
Fe ₂ O ₃	-	-	-	-	-	.41
						11.63
Iron total amount -						38.7%

MR. TEALL states that "the rock is composed almost entirely of spherulites of siderite. The spherulites measure from 1 to 1.5 mm. in diameter and are usually composed of 8 or 10 individual crystals. They are often stained brown at their margins in consequence of the decomposition of the siderite and the oxidation of the iron. Sometimes the spherulites are in close contact with each other and sometimes there is a small quantity of brown interstitial matter. The insoluble residue consists of a very fine mud. The rock is a sphero-siderite."

The specimen was obtained from an horizon between the Deep Mine Ironstone and Knowles Coal at 79 yards above the latter.

Coal-measures.
(Mr. Gibson.)

The Upper Carboniferous rocks of North Staffordshire may with probability be regarded as essentially an estuarine or fresh-water series of deposits. In the waters in which they were laid down small crustaceans belonging to the genus *Carbonia* flourished, sometimes in extraordinary numbers. Constant oscillations of level marked by the intercalation of thin beds of grits characterised the period throughout its duration, but eventually there came a time of elevation, culminating in the formation of a land-surface on which, after vast denudation, the deposits of Bunter age were laid down.

The determination of the zones in the upper part of the Carboniferous system described in the foregoing pages may be found to have an important industrial and commercial bearing. The fact that the Newcastle Limestone lies at the base of grey measures intercalated between an upper group of red strata (the Keele Series) and a lower group of red strata (the Etruria Marls), has enabled MR. GIBSON to detect true Upper Coal-measures in Keele Park, Shutlanehead, and to the west of Leycett. Several points to the west of Madeley Heath and Leycett remain to be worked out, but there seems at present to be little doubt that the Coal-measures of the Pottery coal-field lie not far from the surface under Little Madeley and Craddock's Moss. Evidence has been obtained that the strata on the north-west side of the North Staffordshire anticline do not uninterruptedly descend beneath red rocks (so-called Permian) to the west of Leycett, but rise locally westward under Hayes. The effect of this change of inclination is to bring to the surface strata which lie considerably below the unproductive red series and to bring the principal coals and ironstones within reach further west than might have been expected.

In the Newstead boring, an inspection of the cores having been kindly permitted by MR. GEO. MITCHESON, Mineral Agent to the Duke of Sutherland, the Keele, Newcastle, Etruria, and Black Band series were recognised by MR. GIBSON with their respective limestones in their proper places.

Faults and Flexures.—The North Staffordshire coal-field has been powerfully affected by earth-movements. These take the form of (1) sharp and gentle flexures, the axes of the folds trending north and south or a little east of north; (2) normal faults with large downthrows to the east, ranging in a N.N.W. and S.S.E. direction and continuing for several miles as powerful faults; (3) faults running nearly due east and west, often of large throw but of short length; (4) faults with no definite trend and of small throw.

No conclusive data have been obtained to settle the relative ages of some of these faults. There is reason to suspect that the Bunter formation is involved in the fold of the North Staffordshire anticline. The Apedale fault, with a large downthrow to the east, trending N.N.W., and already traced for more than ten miles, is certainly post-Triassic, as do also seem to be all the more powerful N.N.W. faults. The Bullhurst large

fault, trending nearly N.E. to S.W., appears to be connected with a fault seen at Madeley Manor, which brings red Upper Carboniferous rocks overlain by Bunter beds against strata as low down as the Etruria Marls. The same fault apparently runs underneath the drift deposits of Madeley and appears at Bar Hill Farm, where some highly inclined Bunter Pebble beds are faulted against red Upper Coal-measures. The fault is again lost beneath superficial deposits to Winnington. From this point to Mucklestone a fault with a downthrow to the west has been traced by MR. WEDD. At Normacot an east and west fault with a throw estimated at 250 yards may affect the Trias, but this point remains to be settled.

In any attempt to classify the faults and folds of the North Staffordshire Coal-field it should be borne in mind that the Coal-measure period was one of gentle oscillations, as shown by the recurrence of marine beds amidst those of estuarine origin in the Middle and Lower Coal-measures. During the vast interval between the time of the highest Carboniferous strata and that of the Trias there may have been many geographical changes in the region, but in the end the elevatory forces gained on those of depression and culminated in the Bunter. The connection of the faults and folds with these upward movements and with the downward movements during which the Mesozoic rocks were deposited remains for future investigation. There is some evidence in support of the idea that the Swynnerton Dyke and some of the N.N.W. faults may be of Tertiary age.

Lorne.

In the last two annual statements of the work of the Geological Survey* reference has been made to a small patch of red marls, sandstones, and conglomerates which have long been known to occur at the Bridge of Awe. These strata have been generally regarded as belonging to the Old Red Sandstone, though no fossils had ever been obtained from them. As some of their beds seemed not unlikely to yield organic remains, advantage was taken of MR. TAIT'S renewed search for further ichthyolites among the Lower Old Red Sandstones of the Oban district to subject these strata to a closer examination. As already stated, his labours were rewarded by the discovery of a number of organisms which suffice to show that the strata in question do not belong to the Old Red Sandstone but to the Carboniferous system—a fact of the greatest interest in regard to the geological history of the West Highlands.

The specimens obtained by the fossil-collector included a small number of fossil plants, which, however, were unfortunately in a fragmentary state. Such as they are, they have been submitted to MR. KIDSTON who finds that they consist of stems, rootlets, a fern rachis, and a calamite stem, which last he

* *Annual Report* for 1896, p. 55 ; *Summary of Progress* for 1897, p. 85.

Mr. Peach.) thinks is referable to *Asterocaulumites scrobiculatus*, Schl. While of opinion that the plants have a Calcareous Sandstone (Lower Carboniferous) facies, he is certain that they cannot belong to the Lower Old Red Sandstone. A point in favour of the Carboniferous age of these strata is that a small patch of plant-bearing Carboniferous rocks was detected by PROFESSOR JUDD* on the east shore of the Sound of Mull near Ardtornish, a distance of only 20 miles to the W.N.W. of the strata at Bridge of Awe.

Another piece of evidence in favour of the Lower Carboniferous age of the Bridge of Awe beds is afforded by the occurrence of the cast of a small modioliform shell on one of the specimens with rootlets (T. 3257). This form, though badly preserved, is almost identical with some varieties of *Modiola Maculami*, Portl., one of the commonest shells of the Cement-stone group of the Lower Carboniferous series in Fife, Liddesdale, and the North of Ireland. Three varieties of the shell are figured in Portlock's "Geology of Londonderry and Tyrone."

(Mr. Kynaston.)

In consequence of this discovery MR. KYNASTON re-examined the locality in order to revise his mapping of the ground. The result of this further scrutiny was to convince him that the strata in question at the Bridge of Awe are the highest to be seen in the district, and that they are not overlain by any of the Lorne lavas as he had previously supposed. On the other hand, it might have been expected that any much younger group of strata would have been separated from the Lower Old Red Sandstone and its lavas by a marked unconformability. On the banks of the Awe, however, MR. KYNASTON has traced a perfectly conformable succession from the lavas to the sediments. The lowermost strata of the latter overlie andesitic lavas, apparently identical in character with the normal type of the district, and moreover these lower beds contain a very distinct admixture of volcanic material, the conglomerate frequently showing fragments of andesite besides the numerous quartz pebbles. But possibly this lower band of conglomerate indicates an unconformability, and the volcanic material in it and in the reddish sandy shales succeeding it was derived by erosion from the underlying lavas. MR. PEACH has suggested that there may be in this district lavas of Carboniferous, besides those of known Lower Old Red Sandstone age. He argues that there must be either a great stratigraphical break at the base of the sediments, the tuff-like beds in which were derived from the mechanical trituration of the much older lavas underneath, or a passage upward from the volcanic into the non-volcanic rocks, in which case there would be evidence of a second and younger volcanic series like that of the Campsie Fells, and an unconformability would probably be found to exist between this series and the older lavas of Lorne.

MR. KYNASTON, however, has been unable to discover any sign of a marked break in the continuous succession of lavas in the neighbourhood. He believes that there is here but one volcanic series, that of the Lower Old Red Sandstone, and that there exists

* *Quart. Journ. Geol. Soc.*, vol. xxxiv., pp. 684-685.

here a small outlier of Carboniferous sedimentary rocks which (Mr. Kynass-
overlie the eroded andesitic lavas of Lorne where these abut ton.)
against the great dislocation of the Pass of Brander at Bridge of
Awe.

Isle of Arran.

In the *Summary of Progress* for 1897 the existence of true Coal-measures in the Isle of Arran was announced, and lists were given of the fossils on the evidence of which the identification of strata of that age had been made. During the past year the collections of fossils have been more carefully examined. A portion of the series of fossil plants from the Calciferous Sandstones of the northern part of the island has been gone over by MR. KIDSTON. His examination shows that the plants from these strata have a strong Lower Carboniferous facies. The most conspicuous and common plant is *Lepidodendron rettheimianum*. From Locherim Burn, the locality from which PROFESSOR IVISON MACADAM obtained the plants, a list of which appears in the *Trans. Geol. Soc. Edinburgh*, vol. v. p. 316, he records the presence of *Asterocalamites scrobiculatus*, the same form which he thinks also occurs at Bridge of Awe.

A special collection of plants was gathered from the volcanic zone of the Calciferous Sandstone at the locality near Laggan Shepherd's house on the east coast, where Mr. WÜNSCH obtained specimens of plants exhibiting internal structure in an exceptionally good state of preservation, as described by the late PROFESSOR WILLIAMSON. The collection thus made, consisting of plants not in a very good state of preservation, was submitted to MR. KIDSTON, who believes one of the species to be *Lepidophloios wünschianus*, Williamson (sp.), described by WILLIAMSON by mistake as a *Lepidodendron*. From the finer tufts of this locality he records the occurrence of a species, *Sphenopteris (Rhodea) patentissima*, new to Scotland, the only other British record of it being from the north of England.

City of Edinburgh.

Owing to the widening of the North Bridge in Edinburgh it became necessary that the street leading south from it should be also widened, and this has necessitated the pulling down and rebuilding of the street. The west side having been taken by the proprietors of the "Scotsman" newspaper, extensive excavations for the foundations of their offices have been made beneath what was the old Market Place, revealing a fine section of shales, mudstones, and sandstones resembling many of those so common near the base of the Cement-stone series in the South of Scotland. The strata dip at 10°-15° to the E.N.E. MR. DUNCAN, one of the attendants in the Museum of Science and Art, found in this section a dark seam which contained fragments of plants, *Spirorbis* and ostracods.

As this bed is apparently the lowest from which fossils have been obtained among the rocks that underlie the city, it was thought desirable to search it for further organic remains. MR. TAIT therefore made a collection from it. The fish remains in this collection were submitted to and determined by DR. TRAQUAIR. The Ostracods were named by MR. J. W. KIRKBY. The recognisable remains of plants comprise *Adiantites lindsæformis* (now known as *Rachopteris inequilatera*), *Stigmaria*, and various fern-stems. The worms are represented by *Spirorbis carbonarius* and *S. helicteres*, still attached to some of the plant-remains. The Ostracods are *Leperditia subrecta*, *L. Okeni*, *L. wrightiana* (?), *Kirkbya spiralis* (abundant), *Argillorcia æqualis*, *Aglania cypridiniformis* (?), *Bythocypris subannata* (?). The higher crustacea are represented by the portion of a carapace of *Anthropalæmon*, while fragments of scorpion-skin show the presence of arachnids. Fishes are represented by scales of *Rhizodus* and of a palæoniscid fish.

MR. KIRKBY, in referring to the ostracods examined by him, says:—"By far the most common form is *Kirkbya spiralis*; it is very abundant. All the species are essentially Lower Carboniferous forms; and as a group are characteristic of the lower half of the Cement-Stone Series rather than the upper.

The doubtful things are always met with at low horizons, and had the lot been found in Fife it would not have been higher than the Billow Ness beds." *

This palæontological evidence is quite in conformity with the stratigraphical position assigned to these Edinburgh strata by the Geological Survey.

PERMIAN.

The chief feature in the revision of the "red rocks" of Central England during the past year has been the change made in the area of the so-called "Permian" formations. As already pointed out (p. 126), large tracts of red sandstones and marls in North Staffordshire, hitherto coloured as Permian, prove to be really an upper part of the Coal-measures into which they pass down conformably. And the same change will no doubt require to be made throughout the Midlands as the revision advances.

Leicester-
shire.

(Mr. Fox
Strangways.)

In continuing his field-work along the north of Leicestershire and south of Derbyshire MR. FOX STRANGWAYS has had to modify considerably the older mapping, chiefly in respect to the red rocks. In the district of Ticknall, for example, he has been unable to find evidence for any of the N.E. faults which have been shown to the west of that place; hence the area of the Permian beds (which are quite distinct from the strata now relegated to the Carboniferous system) is considerably more extensive than it has hitherto been represented to be. Thus the

* See J. W. Kirkby, "Zones of Marine Fossils in the Calcareous Sandstone Series of Fife." *Quart. Journ. Geol. Soc.*, vol. xxxvi. (1880), pp. 559-590.

narrow strip of Permian strata mapped to the north-west of the village of Hartshorn really extends down the whole length of the Foremark Valley until it is lost under the alluvium of the Trent at Milton. The other patch of the same marls and breccias shown on the published map at Ingleby is found to come south to the Carboniferous Limestone at Ticknall, on which it lies unconformably. The structure of the ground between Ticknall and the Trent is certainly rather obscure, and different explanations of it have been proposed. MR. FOX STRANGWAYS has obtained some fresh evidence which may help towards a solution of the difficulty. The shales which have been mapped as Coal-measures between Ingleby and Coppy Hill are probably of Lower Carboniferous age. They dip regularly under the fine escarpment of Millstone-grit in which the strata have a distinct inclination of from 5° to 10° towards north-east.

In previous *Annual Reports* of the Geological Survey reference has been made to the newer red rocks of the island of Arran, regarding the true geological position of which no definite evidence has yet been obtained. MR. GUNN was able last year to prolong his mapping of these strata at the northern end of the island. Near the Cock of Arran a detached outlier of them consists of false-bedded bright-red sandstone (like that of Corrie), about 1,000 feet in thickness, and of beds of conglomerate which mainly overlie the sandstone. The conglomerate resembles that exposed in Brodick Bay, and lies probably on the same horizon. As the beds dip seaward numerous landslips have occurred and the hillsides show many gaping fissures.

On the west side of the island similar false-bedded red sandstones occur in the Machrie Water and to the northward of it, but there seems to be no equivalent there of the conglomerates. In this part of the island the younger formation appears as if quite conformable to the Old Red Sandstone below it, so that it is not easy to say exactly where one formation ends and the other begins. The gently inclined newer Red Sandstone of the Machrie Water when traced up the stream gradually increases in the amount of its dip from 10° to 30° or so, as far as the outcrop of a conglomerate which may or may not be part of the Old Red Sandstone. A similar difficulty occurs in the section in the Machrie Burn and on the coast opposite Auchagallon. While it is to be hoped that diligent search will result in the discovery of some fossil evidence which may settle the exact boundary-line, there is meanwhile no doubt whatever about there being here two distinct formations.

TRIAS.

Considerable tracts of the various subdivisions of the Triassic system have been re-mapped during the past year, chiefly in the Midland counties, but partly also in South Wales.

On the south side of the South Welsh coal-field it has been necessary to survey an interrupted strip of Upper Triassic rocks

Leicester-shire.
(Mr. Fox Strangways.)

Arran.
(Mr. Gunn.)

South Wales
(Messrs. Tiddeman and Cantrill.)

South Wales.
(Messrs.
Tiddeman
and Cantrill.)

which intervenes between the edge of the Carboniferous formations and the coast-line of the British Channel. During the past year this survey has been nearly completed by MESSRS. TIDDEMAN and CANTRILL. One of the conspicuous features of these strata is the occurrence among them of a group of conglomerates or breccias chiefly made up of fragments of Mountain Limestone—the so-called Dolomitic Conglomerate. In his recent field-work MR. CANTRILL traced these conglomerates and breccias to the east of Cowbridge; but west of that town the Trias disappears and littoral limestones of Liassic age rest directly on the Carboniferous rocks. Further on again, however, the Trias reappears, and MR. TIDDEMAN has mapped a number of separate areas of it. Of the pebbles included in the conglomerate and breccia, Carboniferous Limestone forms by far the largest proportion, but pieces of chert and occasionally of sandstone also occur. In some parts, as near Porthcawl, marls are almost absent but in others, as near Pyle, they make up a greater thickness than the conglomerates. As explained in previous *Reports*, the marls and conglomerates were contemporaneously thrown down, the latter being merely irregular accumulations of débris at the foot of the Triassic shore-cliffs. The occurrence of foot-prints in the conglomerates, as recorded by PROF. SOLLAS,* proves that the deposit was spread upon a foreshore that was occasionally dry. The finer bands of conglomerate and the marls not infrequently show ripple-marks. Near Porthcawl a cave in the Carboniferous Limestone is noted by MR. TIDDEMAN as having been filled with Triassic gravels, marls, and travertin, and as being therefore of Triassic age.

At Sutton the conglomerates become yellow, and are with difficulty distinguished from Liassic basement-beds, but usually when the upper part of the series is complete it consists of marls, and then runs up without any break into the Rhætic beds. Hæmatite has been found below these conglomerates at Rhythin, but attempts to work it appear to have met with no success.

The mapping of the Rhætic beds from Cowbridge westwards by MESSRS. TIDDEMAN and CANTRILL has given prominence to the fact, not unknown previously, that this formation completely changes its lithological aspect in passing from the east to the west end of the Vale of Glamorgan. At Penarth it consists of shales with thin seams of limestone, but west of Cowbridge it includes thick beds of white quartz-sandstone, which increase westwards until shales become quite subordinate. The upper strata of the Keuper series undergo a corresponding change in the same direction, so that it becomes increasingly difficult to recognise the base of the *Avicula contorta* shales, which served well for a base-line to the Rhætic formation at Penarth.

This development of quartz-grit takes place in that area in which the Secondary rocks pass on to the Millstone Grit of the north side of the great Cardiff and Cowbridge pre-Triassic anticline. From the poor development of the lower red portion of the Keuper Marls it may be inferred that this part of the area stood

* *Quart. Journ. Geol. Soc.* vol. xxxv, p. 511.

above water during much of the Triassic period. That the Millstone Grit formed a large part of the shore-line of the uppermost Keuper and Rhaetic is obvious. Here, therefore, we find the source of the quartz-sand, and the explanation of the close lithological resemblance of the Secondary sandstone to Millstone Grit. South Wales.
(Messrs.
Tiddeman
and Cantrill.)

As neither the stratigraphy nor paleontology of the Rhaetic strata had been fully worked out by the end of last year, an account of them is reserved for a subsequent *Summary of Progress*.

In MR. FOX STRANGWAYS' area already referred to, he has found that the Waterstones cover a much larger area than has hitherto been supposed. They cap most of the high ground about Bretby Park, Repton Shrubs, and Foremark, the pebble-beds only coming out along the valleys. The hill at Foremark Park Farm is not Millstone Grit but Waterstones, as has been shown by MR. HORACE T. BROWN. The Waterstones also stretch further on the east side of the anticline. They are not cut off by the Breedon-Osgathorpe fault, which is pre-Triassic, but extend down the whole length of the valley to the north-east. Leicester-
shire and
Derbyshire.
(Mr. Fox
Strangways.)

The Keuper marls will remain nearly as represented on the published map, but their line of boundary is in many places considerably modified, with the result of reducing the area covered by these marls.

In the revision of the North Staffordshire coal-field it has been necessary to include such portions of the surrounding Triassic districts as were required for the completion of the coal-field maps. MR. GIBSON and MR. WEDD have in this way revised the Triassic areas lying along the western borders of the district. MR. LAMPLUGH has been engaged in those on the south side, while MR. BARROW has taken those to the east. North
Staffordshire.
(Messrs.
Barrow,
Lamplugh,
Gibson,
and Wedd.)

MESSRS. GIBSON and WEDD, in the ground examined by them, have found the lower portion of the Triassic series to present some difficulty in mapping, either from complicated structure or from the thick cover of drift deposits under which so much of the older formations is buried. Thus they have not been able to separate the Upper Mottled Sandstone from the Bunter Conglomerate. In the absence of Lower Mottled Sandstone, the Bunter formation, to the west of the Potteries, may be regarded as consisting of the middle division only. In some cases, as at Beech, the Upper Mottled Sandstone is absent, but in the neighbourhood of Maer and Stableford a brick-red mottled sandstone underlies the Keuper series. The ground, however, is very obscure and evidently traversed by faults.

The most important alteration in the former mapping of the Trias in this part of the country must be made near Pipegate, where MR. WEDD has detected Keuper sandstones in a quarry at Dorrington, in a tract hitherto coloured as Upper Mottled Sandstone.

The base of the Keuper formation is a hard coarse-grained brown and white sandstone, with scattered quartz pebbles. It rests unconformably on mottled red sandstone. At Bearstone the basal beds have been observed by Mr. WEDD to include a

North
Staffordshire.
(Messrs.
Barrow,
Lamplugh,
Gibson
and Wedd.)

light red and white sandstone with characteristic starlike markings standing out on the weathered surface. The Keuper sandstone consisting of pink-brown and white sandstone, with marl partings, has been extensively quarried at Beech, Chapel Chorlton, and Dorrington.

The bottom of the Keuper Marls has been drawn at the horizon where thin fine-grained flags, with pseudomorphs of rock-salt, overlying Waterstones appear. Usually a small rise in the ground marks this horizon. The Keuper Marls are seen to overlap the Bunter at Ashley, Maer, and a little south of Beech.

MR. LAMPLUGH'S attention was given to the development of the Trias to the south of the coal-field, where from the scarcity of rock exposures few detailed observations are possible. The ground is underlain by the Keuper Marls, the bottom of which was met with in the north-western part of the district between Rocester and Upper Tean, where the small tract of Lower Keuper Sandstone at Hollington was examined, as well as the ridge of Bunter Conglomerate to the westward of that place. The downward sequence in this district agrees very closely with that observed by MR. STRAHAN in Cheshire.*

As in Cheshire, the Keuper Marl here passes down gradually into thin flaggy alternations of marl and soft sandstone (Waterstones), and these are underlain by the irregular Lower Keuper Sandstone, which occurs in thick beds, often strongly cross-bedded and sometimes pebbly, with thin marly partings. On the published map this sandstone is not separated from the Waterstones, but their partition, on the lines adopted by Mr. STRAHAN in the neighbouring county, may be found desirable.

As was pointed out by that officer, the lithological characters of the sandstone link it more closely with the underlying Bunter Conglomerate than with the overlying Waterstones and Marl. This question will be more fully considered as the revision of the Triassic areas of the Midlands is carried on.

(Mr. Barrow.) In mapping the tracts of Triassic strata to the east of the North Staffordshire coal-field, MR. BARROW has been led to make some observations bearing on the age of the chief movements by which the structure of the region has been determined. These movements have long been known to be of earlier date than the Bunter formation, which rests with a violent unconformability on the disturbed Carboniferous strata. Not a trace of any faulting or disturbance was detected in the ground surveyed by MR. BARROW last year. At the same time he has noted the pitted pebbles of the Bunter beds as evidence of compression and movement of much later date.

As in South Wales, the pre-Triassic land surface appears to be still preserved under the younger formation. The present topography of the Carboniferous rocks is thus probably not greatly different from that which they possessed in the Bunter epoch. Patches of Bunter beds have been met with in isolated positions

* *Geol. Mag.*, Dec. 2, vol viii., p. 396 (1881), and in the *Geological Survey Memoir on the Neighbourhood of Chester* (1882).

in several parts of the district, even on the hill tops. The broader parts of the Churnet Valley appear to be the old hollow of the Bunter period with a part of the Triassic deposits denuded out of it. (Mr. Barrow.)

The occurrence of red sandstones and breccias lying conformably beneath the Lias of the west coast of Scotland has now been recognised in a number of places, particularly in the district of Strath in Skye and in the island of Raasay. These strata, though unfossiliferous, are regarded as probable equivalents of the uppermost Trias or Rhaetic group of England. Last summer, during a yachting cruise around the coast of Skye, the DIRECTOR GENERAL was joined for a day by MR. HARKER, who was then stationed between Glen Sligachan and Loch Seavaig. While boating along the northern shores of the Sound of Soa, they were fortunate enough to light upon a hitherto unobserved patch of the same group of strata, whereby the area of the Triassic rocks is advanced considerably further to the west. (Director-General and Mr. Harker.)

The Torridon sandstones with the overlying unconformable Tertiary bedded basalts come out in a picturesque range of cliffs along the west side of Loch Seavaig, and sweep round under the huge gabbro masses of the southern Cuillins into the Sound of Soa, as far as a small stream that comes down from the flanks of Garsven, opposite the little harbour in the island of Soa. Where the Torridon sandstones begin to descend to the beach, a band of reddish breccia was observed to come in between them and the bottom of the overlying bedded basalts. This breccia descends to the level of the sea, where it forms a group of ledges and low cliffs. Partly red and partly grey, it is highly calcareous, and passes upward into a sandy limestone. The stones are both angular and rounded. Though to a large extent derived from the adjacent Torridon sandstones, they include also a great number of pieces of Durness limestone and chert.

These breccias, which so closely resemble those of Strath, pass upward into grey and reddish banded and nodular limestones and dark grey shales, possibly indicating the very bottom of the Jurassic series. Unfortunately the rest of the sedimentary succession has been concealed under the vast volcanic accumulations of the district. No fossils were noticed, but during the brief time at the disposal of the observers, there was no opportunity to search even the more promising bands.

At a later period, while the yacht was passing between the islands of Raasay and Scalpa, the DIRECTOR GENERAL observed from a distance some shore ledges obviously different from the prevailing chocolate-red Torridon sandstone. On landing at the place which projects at the extreme north point of Scalpa, he found a small islet, consisting of brecciated conglomerate and red sandstone. As in the Sound of Soa, the enclosed stones consist largely of Durness limestone and chert, as well as of Torridon sandstone, gneiss, and other rocks. The same strata stretch for about a quarter of a mile along the shore, cut through by basalt-dykes. They are faulted against the Torridon sandstones, on which they may also be seen to rest unconformably.

There can be no doubt that they are a prolongation of the precisely similar strata which in the immediately adjacent island of Raasay are seen to emerge from under the Lias.

JURASSIC.

South Wales.
(Messrs.
Tiddeman
and Cantrill.)

Besides the Triassic rocks, the lower parts of the great Jurassic series occupy a number of detached areas in the strip of low ground which intervenes between the southern edge of the South Wales coal-field and the shore of the Bristol Channel. During last year further progress was made by MR. TIDDEMAN and MR. CANTRILL in the revision of these areas. Their mapping affords illustration that not only does the Rhaetic group overlap the Keuper, but that the Lias overlaps both, while at the same time the lowest zones of the Lias are themselves overlapped by higher Liassic strata. It thus happens that not only each formation, but each zone in turn takes locally the position of a basement-bed, and assumes a littoral character, totally different, as a rule, from its normal aspect. In no part of the series is this change more marked than in the Lias, for the massive, tufaceous and more or less conglomeratic shell-limestones of that formation in its near-shore condition, present at first sight but little in common with its usual thin alternating limestones and shales. Six varieties of Liassic shore-deposits have been noted by MR. TIDDEMAN:—

1. Conglomerate, the most obvious beach of all.
2. A consolidated gravelly sand made of fragments of the older rock, together with broken Liassic shells and corals.
3. A similar rock, with larger angular fragments of the old rock sparsely scattered in it.
4. Tufaceous rocks with or without included shells, and often containing fragments or pebbles of the older rock.
5. Oolitic limestone.
6. Reefs, of which 50 per cent. consists of coral growth.

The most extensive overlapping by the Lias takes place along the crest, and to the south of the Cardiff and Cowbridge anticline. Thus MR. CANTRILL finds the Lias creeping across the Keuper and Rhaetic groups between Llandough and Llanbleiddian, and resting on Carboniferous Limestone at Cowbridge and Penllin, while it holds the same relation to the older rock in MR. TIDDEMAN'S ground south of Bridgend and in the Southerndown cliffs.

The stratigraphical relations of these formations to one another repeatedly show that the coast-lines of older Mesozoic time were diversified by eminences which, during the subsidence of the region, passed through the successive stages of promontories, peninsulas, and islands before they were all finally submerged in the Liassic sea. Denudation has disinterred many of these buried crags and exposed to view the Lias resting upon their tops, or the Rhaetic and Keuper piled against their feet, according to the depth to which the process of uncovering has reached. It may be noted

that the principal eminences consisted then, as now, of portions of the Carboniferous Limestone escarpment. South Wales (Messrs. Tiddeman and Cantrill.)

It follows from what has here been said, that the base of the Lias, at any point where it rests on the limestone, may not be the true base of the formation, and, as a fact, MR. TIDDEMAN never finds the lowest band of the Lias, in which *Ostrea* abounds, except where the Rhaetic group is present beneath. In such cases, the abnormal character of the local basement-bed makes its zonal identification extremely difficult.

From Oxford as a centre, MR. J. H. BLAKE is engaged in the revision of the mapping of the Jurassic formations, together with that of the superficial accumulations. Various modifications have been found necessary in the published maps. Some important information has been obtained from a boring made for MESSRS. HANLEY AND CO., at the City Brewery, Oxford, by MESSRS. LE GRAND AND SUTCLIFF, to a depth of 439½ feet. The Jurassic rocks have been pierced down to the Lower Lias, and some interesting features in them have been brought to light, chief among which perhaps is the proof of the existence of the Upper Estuarine series and Inferior Oolite beneath Oxford, and the absence there (unless faulted) of the Upper and Middle Lias. MR. BLAKE, from a careful examination of the cores and from specimens preserved, has compiled the following section of the strata passed through in the bore:—

Valley Gravel, &c.	-	-	-	-	30	feet.
Oxford Clay	-	-	-	-	210	"
Cornbrash	-	-	-	-	17	"
Forest Marble	-	-	-	-	32½	"
Great Oolite	-	-	-	-	88	"
Upper Estuarine Series	-	-	-	-	28½	"
Inferior Oolite	-	-	-	-	16½	"
Lower Lias	-	-	-	-	17	"

CRETACEOUS.

The investigations of the Geological Survey during the past year among the Cretaceous formations have extended from Dorsetshire to Norfolk. They have largely consisted in the examination of special questions connected with the completion of descriptive memoirs. But at the same time the revision of the mapping of these formations has advanced steadily in the course of the re-survey of the southern counties for the completion of the agronomical map of England.

From Maiden Newton as a centre MR. HINXMAN, who was temporarily transferred from Scotland for the purpose, traced the outcrop of the Melbourne Rock and Chalk Rock that mark respectively the limits of the Lower and Middle Chalk; and mapped the superficial deposits of clay and gravel that rest on the chalk. Dorsetshire (Mr. Hinxman.)

The calcareous grit which forms the top of the Upper Greensand in South Dorset, with an average thickness of 6–9 feet, passes to the north of Maiden Newton into a glauconitic gritty sandstone. Between Evershot and Rampisham this bed is only from one to two feet thick, and in places appears to be altogether absent.

Dorsetshire.
(Mr. Hinxman.)

The depression of the chalk plateau west of the Frome Valley, in which lies the village of Compton Valence, is occupied by an inlier of Upper Greensand and Jurassic Clay, these rocks being brought up on a dome with a qua-qua-versal dip. At the western end of the area, the Upper Greensand dips west-north-west at the comparatively high angle of 22° , but at the eastern extremity the beds are inclined to the east at a low angle. The centre of the dome is occupied by stiff blue and yellow clays, which may belong either to the Fuller's Earth or Oxford Clay. There are few good exposures of these clays, and no fossils have yet been detected in them. Another small inlier of the Upper Greensand, let down on the east by a cross-fault, has been mapped a quarter of a mile further to the north.

Wiltshire,
Hampshire,
and Dorset.
(Mr. Bennett)

Further to the east, on the margin of Dorset and in the counties of Wiltshire and Hampshire, MR. BENNETT, working from Salisbury as a centre, in continuation of his previous survey, has completed an additional area of the revision of the Cretaceous rocks. The chief feature of novelty in his examination has been the detection of two previously unrecognised inliers of Upper Greensand at Bower Chalk and Alvediston, and of two new outliers of Reading Beds (sands and pebble-beds) at Pentridge, and to the north-west of Breamore. Some other remarkable peculiarities have been noticed by the same observer on the Chalk Downs near Cranborne Chase. The main escarpment of the Chalk faces the north at Win Green and Winkelbury Hill, and rises to a height of a little more than 900 feet. Along the dip-slope towards Tollard Royal the Chalk has been deeply excavated and two irregular inliers of Middle and Lower Chalk have thereby been exposed. The larger of these inliers occurs between Ashmore on the south-west and Win Green and Winkelbury Hill on the north. It stretches so near to the crest of the Chalk escarpment that only a narrow ridge (50 yards wide of Upper Chalk and 250 yards wide of Middle Chalk) separates that escarpment from the steep scarp formed at the northern end of the inlier above Ashcombe Farm. There indeed the head of the combe is formed by ground which slopes steeply from an elevation of 800 and 900 feet along the crest of the escarpment down to 500 feet around a broad indented hollow which contracts southwards as it merges into Ashcombe Bottom. Equally striking features occur in the south-western portion of this straggling inlier at Quarry Bottom. These dry chalk valleys, like those in Sussex, were probably formed in the manner explained by Mr. C. Reid.*

Oxfordshire.
(Mr. Blake.)

Still further along the strike of the Cretaceous formations, MR. J. H. BLAKE has been engaged upon the revision of the rocks in the district around Oxford. Some alteration has been found necessary in the published maps in regard to the boundary-lines of the Iron Sands (Lower Greensand) which cap the irregular outlier of Portland Beds that lies to the east and south-east of the city. The two most noticeable corrections are perhaps that the

* *Quart. Journ. Geol. Soc.*, vol. xliii., p. 364.

outcrop of Portland Beds between Littleworth and Wheatley has been continued instead of being masked by an overlap of the Iron Sands upon the Kimeridge Clay, and that what was shown as a small outlier of Iron Sands has been joined on, as it really is, to the main mass at Horsepath. South of Waterstock, in the revision of the boundary-lines of the Gault and Lower Greensand, the outcrop of Lower Greensand has been shown beneath the Gault, instead of its being hidden by an overlap of the Gault upon the Kimeridge Clay, as it is represented with a doubtful line on the published map. (Mr. Blake.)

The preparation of a Memoir on the country bordering the Wash rendered necessary some further critical examination of certain portions of the Cretaceous series of Norfolk. The relationship of the Lower Cretaceous rocks of that county to the better known deposits of the same geological period north of the Wash has not hitherto been satisfactorily established. Accordingly, MR. LAMPLUGH, whose close personal acquaintance with the Yorkshire and Lincolnshire types peculiarly fitted him for the work, was detailed to make the required study. (Mr. Lamplugh.)

As the area forms the chief link between the well-developed marine sequence of the Lower Cretaceous Series of the north-east of England, on the one hand, and the scattered and incomplete sections of these rocks in the Eastern Midlands and the widely different strata of the Wealden district, on the other hand, the correlation is of much importance to the student of the Lower Cretaceous rocks of England.

It was hoped that a re-examination of the chief sections, in the light of recent researches farther north, might serve to establish the correlation; and though the paucity and poor state of preservation of the fossils of these deposits in Norfolk, and the peculiarly local facies of such as do occur, have hindered definite conclusions on some points, it is believed that sufficient evidence has now been obtained to indicate, at any rate, the broader outlines of the correlation. These results have been incorporated in the Memoir on Sheet 69 which is now in the press, but may be briefly recapitulated in this *Summary* of the year's work.

In the northern part of Norfolk the Lower Cretaceous Series consists of three distinct lithological divisions—the Lower Sands, to which the term Sandringham Sands has been applied in the Memoir just referred to; the Middle Clays, or Snettisham Beds of the same Memoir; and the Upper Ferruginous Sands or Carstone.

The middle clayey division, however, dies out southward, and the Upper and Lower Sands have then usually been considered inseparable. But it has now been found that before the Snettisham Clay has entirely disappeared, its lower portion is replaced by an irregular band of concretionary ferruginous sandstone, containing numerous marine fossils in the condition of obscure casts, and that this band can be followed after the clay has died out, so that the line between the Carstone and the Sandringham Sands is traceable throughout the district.

In the Sandringham Sands the only fossils which have been detected are fragments of wood and other vegetable relics, and

Norfolk. (Mr. Lamplugh.) these occur so abundantly, unmixed with other remains, in certain thin clayey seams intercalated with the sands, as to suggest that the deposit has accumulated under estuarine conditions; and this inference is strengthened by the general character of the sands.

From the Snettisham Beds a large number of marine fossils was obtained, chiefly in the form of sharp casts in the nodules of ferruginous claystone, which occur in the clays of the pits at Heacham, Lodge Hill, and Snettisham; and our knowledge of the fauna of this horizon has thereby been considerably enlarged. These fossils have been examined in the Paleontological Department of the Survey, and full lists of them are given in the Memoir on Sheet 69 just referred to. They include two species of *Crioceras*, *Belemnites* sp., *Pecten orbicularis*, *Pecten cinctus*, *Pholadomya Martini*, *Thetis Sowerbyi*, *Cardium subhillanum*, *Trigonia scapha*, and many other lamellibranchs, together with several gasteropods and other forms. Associated with these at Lodge Hill and Snettisham, numerous fragments of fern leaves were found, most of which appear to be referable to a Wealden species, *Weichselia (Lonchopteris) Mantelli*. In the ferruginous band which replaces the lower part of the clay south of Dersingham, the fossil-casts are rarely sufficiently well preserved for identification, but so far as could be determined the fauna seemed similar to that of the clay. The nearest equivalent to this fauna is found in the Tealby Limestone of Lincolnshire, and in the corresponding portion of the zone of *Belemnites brunsvicensis* in the Speeton Clay of Yorkshire.

The Carstone of Norfolk has yielded fossils only in a phosphatic nodular band near its base, where *Ammonites Deshayesi*, *Amm. cornuelianus*, *Perna Mulleti* and other characteristic "Lower Greensand" forms have been obtained by MR. W. KEEPING and others. This fauna has usually been considered derivative, but a re-examination of the fossils, and of the bed from which they were obtained, leads to the conviction that the fauna is on its proper horizon. It is not mixed, but is consistent throughout, and is newer than that of the Snettisham Beds. Its equivalent in the South of England will be found either in the lower part of the Hythe Beds or in the upper part of the Atherfield Clay, an horizon which, as stated in the *Summary of Progress* for 1897, is almost unfossiliferous at Speeton.

There appears to have been no break in the sequence of marine conditions from the time of the deposition of the Carstone to that of the Red Chalk in Norfolk, and the Carstone must therefore cover the interval represented in the South of England by the combined Hythe, Sandgate, and Folkestone Beds. The high polish which characterises the coarser sand-grains in the Carstone probably indicates their prolonged trituration on the bed of a shallow sea through the action of currents of medium velocity, in an area receiving accessions of sedimentary material at a very slow rate. The Spilsby Sandstone of Lincolnshire possesses in this respect similar lithological characters, and in both instances the lapse of time covered by the deposit, as

indicated by the changes of fauna, is very great in proportion to the thickness of the bed. Sandstones are probably, for the most part, rocks of rapid accumulation, but those of the type above described (which are not confined to the Lower Cretaceous rocks) evidently form exceptions to the general rule. In the Secondary rocks such sandstones are frequently associated with dark phosphatic nodules, which again are indicative of areas of slow deposition.

To sum up the history of the Lower Cretaceous Series of Norfolk, we regard the Sandringham Sands as, in part or wholly, of estuarine origin, and presumably, for reasons fully discussed in the Memoir on Sheet 69, equivalent to some portion of the Tealby Clay of Lincolnshire. The Snettisham Beds, with their strongly localized and incomplete fauna, intermixed with macerated vegetable remains which increase in quantity southward, indicate the proximity of land and perhaps the presence in this area of a quiet inlet receiving land-drainage. They have been deposited at about the period of the formation of the Tealby Limestone and "Roach" of Lincolnshire. And the Carstone, like that of Lincolnshire, represents a shallow open sea which ushered in the period of gradual and widespread depression during which the Upper Cretaceous System in England was accumulated.

In the preparation of his monograph on the Upper Cretaceous formations of England MR. JUKES-BROWNE has had occasion to consider with great care the accepted nomenclature of the various subdivisions of the rocks. He has found it necessary to introduce a new name for the Gault and Upper Greensand formations. He does not propose to abandon the use of these familiar names, but to retain them for the argillaceous and arenaceous deposits which have received separate colours on the maps of the Geological Survey. Their union, however, under one name is intended to show that they are not regarded as divisions of independent chronological importance. The name proposed is *Selbornian*, taken from the village of Selborne in Hampshire, which is so well-known from the descriptive letters of Gilbert White. Near Selborne the Malmstone attains its greatest thickness, being no less than 180 feet thick, while the underlying "Gault" marls and clays are about 100 feet, so that the whole has a thickness of 280 feet.

The Selbornian stage will include the Red Chalk of Norfolk, Lincolnshire and Yorkshire, as well as the Gault, Malmstone and Upper Greensand of more southern counties. Where fully developed it is divisible into four palæontological divisions or zones, which in descending order are—(1) that usually known as the zone of *Pecten asper*, which, however would be more conveniently called that of *Holaster fossarius*; (2) the zone of *Ammonites rostratus* with its local sub-zone of *A. varicosus*; (3) the zone characterised by *Ammonites lautus*, *A. dentatus* and *A. interruptus*; (4) the zone of *Ammonites mammillatus*.

A consideration of the facts connected with the occurrence of *Ammonites mammillatus* in England and France has led MR. JUKES-BROWNE to attach the sands which contain this Ammonite

Norfolk. (Mr. Lamplugh.)

Cretaceous nomenclature. (Mr. A. J. Jukes-Browne.)

Cretaceous
nomencla-
ture. (Mr.
A. J. Jukes-
Brown.)

to the Gault rather than to the Folkestone Beds. The zone of *A. nemumillatus* is of small thickness in England, but over a large area of France it is from 20 to 30 feet thick, and moreover in that country this species ranges up into and is not uncommon in the clays of the *A. interruptus* zone.

TERTIARY.

The areas in which rocks of Tertiary age have been mapped last year by the Geological Survey lie in the south of England and the west of Scotland.

Hampshire.

(Mr. Clement
Reid.)

MR. CLEMENT REID, who is charged with the revision of the Hampshire Basin, was engaged in the completion of various maps and Sheet-memoirs connected with that region. This indoor work has included the preparation of the following maps for publication:—Sheets 315 (Southampton) and 316 (Fareham), which were unfinished at the time of MR. WHITAKER'S retirement and the withdrawal of MR. HAWKINS to the office. The necessary field-work for the completion of these two sheets has been finished by MR. REID, and the maps will be sent to the engraver during the present winter; Sheet 328 (Dorchester) has been finally corrected and published.

Two short Memoirs, on Sheets 329 (Bournemouth) and 334 (Eastbourne), have been written and published during the past year. Another Memoir, on Sheet 328 (Dorchester), is well advanced and will be completed this winter.

A special Memoir, on the Water Supply of Sussex, prepared by MR. REID in conjunction with MR. WHITAKER, relates to a large extent to the Hampshire Basin. It is now in proof, and will be published early in the present year.

The present indoor work here noticed has taken so much time that it has been impossible for MR. REID to make much progress with the general Memoir on the Hampshire Basin. It is believed, however, that this year will see the completion of all the field-work of the district, only the Ringwood area being now left. It may also be possible to finish within the same time Explanatory Memoirs to all the Sheets of the map that are complete.

The past season's work has not yielded any striking scientific results, for the area examined is nearly surrounded by districts mapped in previous years and mentioned in former Reports. Considerable doubt exists as to the exact correlation of many of the Eocene strata, which rapidly vary both in lithological character and in thickness, and seldom yield any fossils. The mapping is thus necessarily lithological, and for the present the question must remain uncertain whether the Bagshot pebble-beds of the Botley district really represent the freshwater Lower Bagshot series of the Isle of Wight, and whether the similar pebble-beds lower in the series truly belong to the Reading Beds, or represent the basement-bed of the London Clay.

Dorset.

While engaged in mapping the Cretaceous formations of southern Dorset, MR. HINXMAN came upon a small patch of sand and gravel, presumably of Bagshot age, on the down between Compton Valence and Winterborne Abbas. A pit-section of these deposits shows 8–10 feet of rolled flint-gravel with many pebbles of vein-quartz, and white and grey quartzite. The gravel is interstratified with, and passes down into, yellow and orange gritty sand. Small deposits of a similar character have been mapped south of Frampton, and on the hill between Maiden Newton and Sydling St. Nicholas. (Mr. Hinxman).

Norfolk.

Some additional particulars have been obtained by MR. REID (Mr. Reid) regarding the Pliocene and Pleistocene deposits of the Norfolk coast. A new well for the supply of water to Mundesley has furnished a section of Pleistocene, Pliocene, and Cretaceous strata, which corresponds with and supplements the section displayed in the coast-cliffs. The principal points of interest are the occurrence of loams with Arctic plants at the base of the Glacial deposits, and resting on quartzite-gravels belonging to the Cromer Forest-bed; the tracing of Weybourn Crag with the characteristic *Tellina balthica*, down to the Chalk at about 20 feet below Ordnance datum; and the discovery of soft greyish sandy Chalk of the peculiar Trimingham type, and like that Chalk, full of *Ostrea larva*. The tracing of the Chalk beneath undisturbed Pliocene beds is especially important in face of the discovery that Boulder-clay passes beneath the Chalk at several points near Trimingham, and that the enormous disturbed mass, half a mile in length, there seen, may therefore be a transported block entirely detached from the solid rock. This well is not yet completed, but apparently yields a good supply of water.

Another somewhat similar well has been successfully completed at North Walsham. It shows:—

	Feet
Glacial Gravels - - - - -	48
Contorted Drift - - - - -	26½
Glacial Sands (the fine dust-like sands of Mundesley Cliff) - - - - -	22
Till - - - - -	4
Forest-bed (quartzite-gravels and sand) - - - - -	22
Chillesford Clay? - - - - -	½
Crag with shells - - - - -	18
Chalk - - - - -	109
	250

The Crag is apparently Chillesford or Norwich Crag, though the mollusca are too few to decide the question. *Tellina balthica* is not among them.

A third Eastern County well is of sufficient interest to be mentioned, as showing an exceptional thickness of Upper Pliocene. At Messrs. Youngman and Preston's Brewery at Lowestoft, situated at

(Mr. Reel.) the foot of the old cliff, a boring has been carried about 180 feet below the sea-level without piercing the Crag, the lowest beds reached being apparently Norwich Crag. This rapid thickening of the Pliocene beds, when traced towards the North Sea, corresponds with what occurs in Holland, and the occurrence of nothing but shoal-water fossils at all depths on both sides seems to support the idea that the present North Sea is largely the result of Pliocene or Pleistocene depression—a view that will explain also the discovery of numerous remains of Pleistocene land-mammals on the Dogger Bank, in the middle of the North Sea.

Scotland.

In Scotland the rocks that can be assigned to a Tertiary age consist almost entirely of volcanic and plutonic masses, which are chiefly developed on the west side of the country, and more particularly among the Inner Hebrides and in the basin of the Clyde. During last year MR. HARKER has continued his survey of the Cuillin Hills, in Skye, where he has mapped an exceedingly rugged group of mountains in greater detail than has ever been before attempted among the igneous rocks of this country. MR. GUNN, in the northern half of Arran, has made further progress with the survey of the interesting plutonic masses, which are now regarded as of Tertiary age. In other parts of the West Highlands more or less interesting examples of the Tertiary igneous series have been encountered.

Igneous Rocks of Skye.

(Mr. Harker.) With regard to his recent field-work in Skye, MR. HARKER has furnished the following report:—

Basaltic lavas with intruded sills.—The further progress of mapping on the basaltic plateaux to the north and west of Sligachan, of which some twenty square miles have been completed during the past season, shows that the rocks do not differ in general characters from the description given in the *Summary of Progress* for 1897. Intrusive sills continue to play an important part in the structure of the ground, and indeed it is noticeable that they become thicker and more conspicuous as we pass northward and westward from Sligachan, *i.e.*, away from the mountain district. Their source is evidently quite distinct from that of the great plutonic intrusions. The sills attain their fullest development in what are now (in consequence of the superior durability of the sill-rocks) the highest parts of the plateau district, and here they usually surpass the lavas themselves in thickness. For instance, in a section through Monadh Meadale and Beinn Totaig, twenty sills have an aggregate thickness of 1,200 feet in a total of 2,000 feet. As elsewhere, two, three, or four sills often come together without any intervening lavas.

The rocks composing the sills are not all of one type, but are commonly either basalts or diabases. On the summit of Roineval, and at other places farther north, are thick sills of a beautiful porphyritic dolerite, and with this is sometimes associated a trachyte with a remarkable fissile structure, thus forming composite sills. Dykes of both rocks occur in the district, and have probably been the feeders of the sills, but composite dykes of the two rocks together have been detected in one or two localities only. (Mr. Harker.)

Composite sills of granophyre and basalt, of the type common in the Lias of the Broadford district, are rare among the basaltic lavas, but one fine example is seen in Allt an t-Sithean, near Sligachan. A composite dyke of similar structure, *i.e.*, with granophyre flanked on each side by basalt and each rock containing *débris* of the other, occurs close at hand, and can be traced nearly to the sill, of which it has presumably been the feeder. Sills of a similar basalt (with porphyritic feldspars and corroded quartz grains) occur at one or two places close to the granite of Glamaig, and also entangled in the granite both on that hill and on the shoulder of the neighbouring Druim na Ruaige. The relations are probably the same essentially as in the symmetrical composite sills already referred to, but here the greater volume of the acid rock-magma has in great part destroyed the basic rock. For a considerable distance the granite is crowded with little round patches and spots of half-digested basalt.

The peculiar basic sills just mentioned are to be referred to an epoch very slightly anterior to the intrusion of the granite, but the ordinary basic sills, so abundant among the basaltic lavas of this district, must be younger than any of the great plutonic intrusions. This appears from the fact that the sills die out on approaching the tough, splintery, metamorphosed lavas which border both gabbro and granite, and are wholly wanting among the considerable patches of basalt lavas which are enveloped by those plutonic rocks.

The north-western border of the Cuillin Hills has been mapped as far as the mouth of Coir' a' Ghreadaidh. The junction here is an irregular one, the gabbro sending tongues into the basaltic lavas and enclosing portions of those rocks. No prolongation of the acid volcanic group of Bruach na Frithe has been detected, except a few relics of banded rhyolite and tuff entangled in the gabbro on the slopes of Sgùrr Thuilm.

The bedded basalts have also been mapped along the southern border of the mountains as far west as Garsbheinn, with the exception of a short length of coast-line at the head of Loch Scavaig, where the gabbro of the Cuillins comes down below sea-level. As elsewhere, the basalts clearly underlie the gabbro. There is no great thickness of them at this place, for the Torridon Sandstone soon emerges from beneath them on the western side of the bay, and the Lias on the eastern side. Tongues and veins of granite often occur in the lavas or along their junction with the gabbro above or the stratified rocks below, and on the shore west of Camasunary the granite makes a

(Mr. Harker.) considerable strip. It is probably to this rock rather than to the gabbro that the highly metamorphosed state of much of the basaltic lava is to be ascribed. The rock is a white hornblende-granite of the type found on the eastern side of the Blaven range, and differs in some respects from the yellower granite of the Red Hills. In particular, it has much less tendency to the 'granophytic' structure. It is often crowded with enclosed fragments, in some places of Lias shales, in others of basalt.

Gabbro of the Cuillins, with intruded basic sheets.—About twelve square miles of the mountains have been mapped during the year, including the north-western part of the group and the basin of Coruisk. As before, the structure of the ground was found to be extremely intricate, the complexity arising from three causes—(a) the frequent inclusion of patches of the basaltic lavas and agglomerates in the gabbro, especially near the margin of the area; (b) the composite nature of the gabbro mass itself, which is built up of many intrusions traversing and interlacing with one another; and (c) the multiplicity of later basic intrusions in the forms of dykes and sheets which intersect the gabbro.

Most of the enclosed patches that have been mapped are of the volcanic agglomerates, but this may be due in part to the fact that these are more easily detected than the highly metamorphosed patches of basalt. In places, however, the agglomerate also is so much altered as to become very obscure, the finely divided matrix entirely losing its character. It seems probable indeed that the xenoliths of gabbro and basalt enclosed in the gabbro in many parts of the Cuillins are derived in some cases from the destruction of enveloped portions of volcanic agglomerate rather than from solid masses of gabbro and basalt, although this certainly cannot be the source of the xenoliths in all cases.

Although abrupt junctions of different kinds of gabbro, *e.g.* of coarser and finer-textured types, constantly attest the complex structure of the great gabbro mass, it has not been found practicable to take account of this in the mapping of the area. One type only is so distinct in appearance from the rest as to be easily followed by eye even at a distance, and has been mapped as an indication of the fashion in which the several component intrusions of the great laccolitic mass intersect and interlace with one another. This rock is conspicuous by the orange-red colour which it assumes on an exposed face, and is further characterised by an extremely rough surface due to little pits. These pits mark the position of xenoliths of a less durable type of gabbro, with which this peculiar rock is often crowded. It is confined to the western part or main range of the Cuillins, where it occurs sometimes in considerable bodies, sometimes in the form of dykes traversing the more normal gabbro, and in visible connection in certain cases with the larger bodies. On the other hand the same or a closely similar rock is found in the neighbourhood of the Mad Water (Allt a' Chaoich) entangled in, and veined by, a coarse-grained gabbro of normal type.

Like the area already reported on, the gabbro tract surveyed (Mr. Harker.) during the past year is remarkable for the great profusion of minor intrusions of basalt and diabase which traverse it in the form of a series of parallel sheets. The dip of these sheets follows the rule already pointed out, being always towards the centre of the whole gabbro area. Thus at the head of the Coruisk valley and on the neighbouring mountains the dip is E., around Loch Coruisk N.E., on Sgùrr na Stri N., and on Blaven N.W. As before, these basic sheets are found to cease abruptly at or near the outer edge of the gabbro area, nor do they enter the granite of Marsco, Druim an Eidhne, etc., which in part breaks through the gabbro. Further, there are tracts in the gabbro itself where the sheets are almost wanting. This is the case along the Sligachan River, on Druim an Eidhne, and on the shores of Loch na Crèitheach and Loch Coruisk; all places where the base of the great gabbro laccolite is not far beneath the surface. At the base of the gabbro, as seen along the *outer* boundary of the area, the sheets are abundant, and they occur in the granite which is exposed along the outer (eastern) base of the Blaven range.

Dykes intersecting the basaltic lavas and gabbro.—Basic dykes continue to be met with in great profusion both in the basalt and in the gabbro area. Where the rocks are well exposed, the field-maps often show as many as a hundred dykes in a square mile, presenting a remarkable contrast to the granitic tract, where an equal area contains on an average only five or six dykes at most. The distribution of the dykes is, however, not uniform either on the basalt plateaux or on the gabbro mountains. The comparative fewness of dykes on some of the higher moors is doubtless to be ascribed to the difficulty they experienced in penetrating the massive sills of which these elevated plateaux are mainly built. There are also places relatively free from dykes within the gabbro area, and this, too, is probably not without significance. Thus the basic dykes are almost wholly wanting between Loch a' Choire Riabhaich*, and the mouth of Harta Corrie. This may plausibly be explained by the protection afforded by the underlying granite, which is seen on Druim an Eidhne passing under the gabbro. Farther north, in the Sligachan valley, where the contact of gabbro and granite is vertical, the usual dykes occur in the former rock up to the junction. Again, the granite of Ruadh Stac and Loch an Athain undoubtedly extends for some distance eastward beneath the gabbro of the Blaven range; and accordingly we find dykes far less numerous on the western than on the eastern slopes of that range. Another part of the gabbro area in which dykes are few is that between Loch Scavaig and Coire an Uaigneis, along the south-western side of the Coruisk valley. We have no certain evidence of the existence of subterranean granite here, but it is possible that the granite seen rising above sea-level on the shores

* The southerly tarn of this name, near Loch Coruisk, not the one near Sgùrr nan Gilleann.

(Mr. Harker.) of Loch Scavaig is prolonged in this direction: indeed dykes and veins resembling the known apophyses of the granite are found. The mapping during the past season has given additional confirmation of the fact that the fewness of dykes in the granite does not imply the posteriority of that rock to the majority of dykes in the district, but is due to the resistance which it opposed to their passage. The *smaller* bodies of granite and the offshoots from the larger masses are as freely traversed as the neighbouring gabbro and basalt. Another rock which is commonly poor in dykes is the volcanic agglomerate, and we even find basalt dykes which traverse the gabbro stopping abruptly at the junction of an enclosed patch of agglomerate. Petrographically, the basic dykes present a variety of types—diabases, dolerites, and basalts—mostly without any special peculiarities. Olivine conspicuous to the eye is not often seen, excepting in a group of porphyritic olivine-basalts (specific gravity 2·86—2·89) restricted to the granite area.

Dykes of other than basic composition make up but a small proportion of the whole. The trachyte-dykes already mentioned are, however, well represented in some parts of the basalt area, especially in the neighbourhood of Drynoch. Like the basic dykes, they follow a very general N.N.W.—S.S.E. direction. The rock composing them is fine textured and without conspicuous porphyritic crystals. It has a specific gravity 2·64, and consists almost wholly of slender prisms of felspar, both orthoclase and oligoclase, with a fluxional arrangement, rare flakes of biotite being the only other constituent. It resembles generally a rock previously noted, which occurs in numerous dykes in the Broadford district; but it has less of the potash and more of the soda-bearing felspar. The Broadford dykes give specific gravities of 2·50 to 2·55.

True acid dykes are more uncommon on the basalt-plateaux, and they are rarely met with in the part of the gabbro area surveyed during the past year. The most interesting group is that which traverses the gabbro and volcanic agglomerates and tufts of Druim an Eighne (Drum-hain), and is characterised by a beautiful spherulitic structure and fluxion-lamination. Some of the spherulites are from an inch to two inches in diameter, with a complex plumose structure. These dykes are near the fine-textured and often spherulitic margin of the granite, and many of them can be traced into continuity with it.

Isle of Arran.

(Mr. Gunn.) Of the well-known granite of Arran which forms the picturesque mountain-group in the northern half of the island, the greater part has been surveyed by MR. GUNN. He has now completely traced its boundary-line with the surrounding rocks. Some of the finest junctions of the granite with the schists, which show the intrusive character of the igneous rock in North Glen

Sannox were described more than a century ago by HUTTON,* and (Mr. Gunn.) have since been often referred to, but other junctions quite as striking occur on the east side of Glen Catacol at Madadh Lounie and in several places north of Meall nan Damh. The granite maintains generally its ordinary coarse character near its junction with the schists, but there are several places where it is fine-grained at the margin.

Several writers have described a finer-grained granite in the interior, without attempting to define its exact boundaries. It is intrusive in the coarser variety which surrounds it, and is therefore of somewhat later date, but both evidently belong to one great period of plutonic action, as they have generally the same sets of joints, and they are alike penetrated by all the varieties of dykes (quartz-porphyry, felsite, pitchstone, basalt, &c.). The finer kind of granite occupies nearly all the west side of the Iorsa Valley, so that on this side the coarser variety is but a comparatively narrow strip, varying from one mile in width to not more than a furlong at Iorsa Loch. On the east of the Iorsa Valley most of the granite is of the coarser kind, and the boundary between it and the fine (part of which was mapped by the present DIRECTOR GENERAL in 1872) is tortuous, some bays of the fine being almost detached and surrounded by the coarse. All the peaky hills are formed of the coarse kind, the finer variety forming rounded or flat-topped hills, generally of lower elevation. Usually the fine variety breaks up into small slabs, which often so entirely cover the surface of the ground that no solid rock is observable. The débris of this rock is nearly white in colour. Occasionally, however, the finer granite becomes coarse, and then breaks up into larger blocks, and forms crags. Good junctions of the two granites are to be seen on the south side of Beinn Bharrain, on Sail Chalmadale, and in Glen Easan Biorach.

In addition to the main mass of finer granite, numerous small dykes and sheets of it have been intruded into the coarse in various places; but most of these are not large enough to be separately mapped. Sometimes, however, larger intrusions of this character are met with. In one of these, near the head of Glen Sannox, on the south side of Caisteal Abhail, where the rock has a markedly jointed structure, a closely laminated band of fine granite about nine feet in width may be traced for a hundred yards or more. This is a peculiar rock, and differs from the fine granite which surrounds it in having an approach to a linear arrangement of the quartz in the rock. It weathers into very thin plates or slabs, and looks at first sight more like a schist than a granite. It, however, has its laminæ dipping steeply to the west, exactly in the same way as the joints do in the adjoining fine granite.

The majority of the igneous dykes in the island of Arran are newer than the granite, but a few are certainly of older date.

* In the unpublished third volume of his *Theory of the Earth*, of the MS. of which a surviving portion is about to be given to the world by the Geological Society. Hutton's observations were made in the year 1787.

(Mr. Gunn.) One of these has already been described from the Cnocan Burn dam south of Goatfell, and another was met with this year at Creag nan Gobhar on the west side of Glen Catacol. In the latter case veins of granite penetrate the dyke, which has been changed from a basalt to a diorite.

Dykes of various kinds seem to be nearly as numerous in the granite as in any of the other rocks of the island. Many basalt dykes may be seen along the west shore from Machrie Bay northward, and along the northern part of the island, but few of them can be identified with those met with in the interior. Many are small and their courses irregular. The largest occurs between Imachar and Balliekine, and is in places 100 feet in width.

Dykes of various kinds have been traced for long distances in the granites, and one in particular, a quartz felsite, which follows a north and south course over Beinn Tarsuinn and the south-east of Beinn Nuis, can be followed for more than two miles. On Beinn Tarsuinn it seems to be quite 40 yards wide, but it divides into several branches striking to the north. To the south-east of Beinn Nuis its width is 75 feet.

To the north of Caisteal Abhail a remarkable dyke of porphyritic pitchstone of a dark green colour, and which is beautifully columnar, may be traced for many yards by the columns which lie about on the surface, and vary somewhat in form as well as in size. None of the rock, however, is actually seen here *in situ*.

Argyllshire.

Between the vast basalt plateaux of the Inner Hebrides and the complex protrusions of Arran many less conspicuous illustrations of the Tertiary volcanic activity may be observed. During the past year some volcanic necks have been met with in the west of Argyllshire, which, though their age cannot be definitely fixed, are not improbably referable to the Tertiary period. They belong to the same class as those formerly described from western Ross-shire and Raasay.

District of
Loch Eil.
(Mr. Grant-
Wilson.)

One or two of these hitherto unobserved vents have been detected by MR. GRANT-WILSON among the hills on the north side of Loch Eil, where they pierce the prevalent quartzose flagstones of that part of the Highlands. The largest of them forms a curiously knobby summit to the mountain known as Stob a Ghrianain (Sunny Point, 2,420 feet). The hill top being free from drift, the form of the orifice can be clearly made out. In ground-plan it is somewhat bow-shaped, with the curved side towards the south-east. Its extreme length is 730 yards, and its breadth 266 yards. At the north-west corner the more or less vertical wall of the vent is seen. The material that has filled up the orifice is an agglomerate, which is occasionally very coarse. In some parts it is mainly made up of fragments of the surrounding micaceous flagstones. Elsewhere it consists of an igneous matrix, enclosing fragments of flagstone, which are mostly

subangular. Some of these are wrapped round in a finer matrix of igneous material, but the chief rock is a decomposing basalt. The rounded flagstone fragments may have acquired their shape from attrition in the volcanic chimney during successive explosions. On being broken open they show an altered and baked outer surface surrounding a less altered core. One of these rounded fragments was examined by MR. TEALL, who reports regarding it:—"[8197] Quartz-biotite granulite. The optical characters of the biotite have been more or less destroyed. The mineral is turbid, feebly pleochroic, and without the strong characteristic double refraction."

District of
Loch Eil.
(Mr. Grant-
Wilson.)

One of the largest blocks of flagstone measures 15 feet $\times$ 12 feet $\times$ 5 feet. It thus contains 900 cubic feet, and must weigh about 70 tons. This block is clearly seen to have been traversed by a granite dyke prior to its being broken off from its parent source, so that the volcanic episode belongs to a far later period than that of the granite intrusions. In the matrix of the agglomerate, augite, olivine, volcanic glass, and mica are common, while the bulk of the magma that was disrupted by explosions seems to have been composed of basalt. A specimen of this basalt was submitted to MR. TEALL for examination, who remarks regarding it:—"[8198] Compact black basalt, containing numerous small fragments of biotite-granulite, and probably also detached mineral grains derived from the granulite. The basalt itself is composed of serpentinous pseudomorphs, in part at least after olivine, and a ground-mass of microlitic augite, magnetite-dust, biotite, and a colourless apparently isotropic base. The true character of the ground-mass can only be seen in very thin sections with a high power. No felspar undoubtedly belonging to the basalt has been detected. The rock has the structure of the nepheline- or analcime-basalts, and is probably referable to this group."

This neck, as it now exists, is clearly a portion of the original volcanic chimney, any overlying and surrounding cone of detritus which existed having been removed by subsequent denudation. Another small "neck," about 50 yards in diameter, is seen in the channel of a rivulet 700 yards to the south-west of the Stob Ghrianain. A third vent lies 250 yards to the S.E. of the 2,385 feet cairn on the Druim Fada. It is oval in shape, 80 yards long, and stands up prominently above the surrounding flagstones. It is almost entirely composed of small pieces of flagstone and quartzite embedded in a fine-grained ashy matrix.

Nearly forty miles to the south of the group of vents above Loch Eil, MR. SYMES has come upon another neck on the moorland between Loch Feochan and Loch Scamadale, about six miles south from Oban. This example presents a number of peculiarities. In the first place, it rises amidst the lavas of Lorne, so that it must be of later date than some part of the Lower Old Red Sandstone. In the second place, it is filled up with acid and not basic material; and lastly, it appears to be connected with some of the younger (presumably Tertiary) dykes, so that in this way it supplies more definite information as to its probable age.

Lorne.
(Mr. Symes.)

Lorne.
(Mr. Symes.)

This neck is pear-shaped in plan, narrow at the north end and widening southward, its maximum length being about 120 feet. It is filled with a coarse agglomerate, some of the blocks in which measure two or three feet in diameter. The fragments consist largely of a remarkable greenish rhyolitic rock with exquisitely developed flow-structure, but they also include pieces of the surrounding andesitic lavas, of the pink biotite-andesite, which occurs in dykes and sills in the Lorne volcanic plateau, and of some basic rocks like the material of many of the Tertiary dykes. While the neck pierces the andesitic lavas and their associated porphyry dykes, it appears also to truncate one of the numerous rhyolite dykes of this district, to which reference will presently be made. Immediately to the south of it, a broad dyke of rhyolite or trachyte appears, exactly similar to the peculiar rock of which the blocks in the neck so largely consist. This dyke is one of the composite kind so abundant in Skye, for it is flanked on either side by a narrow basic dyke. A little further south, in the ravines of the Eas Ruadh, which descends into Loch Seamadale, similar rhyolites or trachytes pierce the andesitic lavas, and are again accompanied by marginal bands of basalt. In one example the acid rock may be seen to enclose a portion of a dyke so highly basic as almost to become a peridotite. These rocks are obviously of far younger date than the age of the Lower Old Red Sandstone. The peculiar characters of the acid material and its association in compound dykes with basic walls seem to link these rocks with the Tertiary volcanic series of the west of Scotland. If this be established as their true geological horizon, they furnish fresh evidence of the wide extent and variety of the phenomena of dyke-intrusion during older Tertiary time.

A specimen from one of these acid dykes was sliced and submitted to MR. HARKER for petrographical determination, and he has supplied the following note respecting it:—

"A dull white compact-looking rock with a few little glistening specks, which are crystals of quartz and felspar. The slice shows scattered porphyritic crystals, usually less than $\frac{1}{8}$ inch, of quartz in good pyramidal crystals, and felspars (albite and sanidine) sometimes intergrown in microperthite fashion. The ground-mass is essentially of felspar and quartz, the latter evidently in great part of secondary origin. The felspar is in bunches of little prisms, but the original structure of the rock is much obscured. It seems to belong rather to the rhyolitic than to the trachytic family. The secondary quartz of the ground-mass might be derived from the rock itself, or from an extraneous source, but the porphyritic quartz seems to mark the rock rather as one of acid composition, since the felspars are doubtless all alkali-felspars. Leaving out of account rocks of the dacite family (which is not in question here), porphyritic quartz crystals may be taken as characteristic of rhyolitic rocks of intrusive type; in the rhyolitic lavas they are often wanting."

(Director
General.)

At great distances from the main centres of Tertiary volcanic activity, basic dykes having a prevalent north-westerly trend continue to be abundant in the ground most recently surveyed in the west of Scotland. They are subject to local augmentations of number, and in some places become so plentiful and lie so close together that it is difficult, or impossible, to represent them all,

even on maps on the scale of six inches to a mile. As the survey (Director has advanced south from Oban, one of these tracts of prolific dyke- General.) intrusion has been entered. Admirable sections are laid bare along the coast-line, where the dykes may be studied both in ground plan and in vertical section.

Some instructive sections may be here referred to which are visible along the shores of the island of Seil, to the north of Easdale. The prevalent rock of the island is the black slate which has so long been quarried here and on the opposite island of Easdale. These slates are traversed by numerous dolerite dykes, which occasionally throw off tortuous interlacing veins. It is interesting to note that where the basic rock assumes these ribbon-like or filamentous forms, it has undergone the characteristic decomposition into "white trap," which is so generally observable where basic material has been injected into rocks of a more or less carbonaceous composition. The proportion of carbon in these black slates must be small, but it has been sufficient to superinduce this peculiar type of alteration.

One of the most striking sections on this coast is furnished by a compound dyke which cuts the slates on the beach about a furlong south-east from the schoolhouse. This intrusion is made up of at least ten bands of dolerite, which, though in a general sense parallel to each other, occasionally diminish in thickness, bend in their course, and thus allow wedges of the surrounding slates to come in between them. Where no such foreign intrusions appear, the whole igneous mass might at first be taken for a single broad dyke, but a little examination discloses that its individual bands are in several cases separated from each other by a selvage of black glass, which is sometimes two inches thick, but dwindles down to a mere film or glaze on the wall of the dyke. The dolerite assumes an exceedingly coarse grain for several inches before it is succeeded by the vitreous layer. Here and there strips of glass lie within the body of a dyke some way back from the wall, without any evidence that they there mark outer margins of distinct dykes. One of the dykes presents a number of cavities, some of them three or four inches in diameter, which are lined with small pea-like spherules of the same black glass. MR. SYMES has found that many of the dykes have a spherulitic structure at their outer margins, the spherules being grouped in rows like those observed by MR. CLOUGH in Skye, and that these rows or chains are sometimes inclined to the horizon at an angle of 10° to the S.E. (as at Gallanach to the south of Oban), as if the molten magma had ascended in the fissure from a south-easterly direction.

In the district surveyed by MR. GRANT-WILSON both to the north and south of Loch Eil many dykes of presumably Tertiary age have been met with. Thus on the ridge of Druim Fada, already referred to for its volcanic necks, a group occurs of which the largest is not more than four feet broad. On the west side of Glen Albyn they are more numerous; several cut the diorite of

Dykes in the Loch Eil district. (Mr. Grant-Wilson.)

Dykes in the
Loch Eil
district. (Mr.
Grant-
Wilson.)

Glen Loy and exhibit chilled edges. A specimen from one of these examined by MR. TEALL is thus described by him :—

"[8289.] Basalt.—Under the microscope a few microlites of felspar and pseudomorphs after skeleton crystals of olivine are seen in a deep brown matrix which shows some action on polarised light, but which must originally have been a tachylite. There are a few minute black grains (magnetite), but most of the iron was obviously retained in the glass. The basalt shows a slight banding parallel with the junction."

Several basalt dykes are also exposed in the stream draining the Monadh Beag. Close to the second milestone on the road leading from the Corran to Conaglen, two dolerite dykes cut the granite. Examined under the microscope by MR. TEALL, one of these specimens [8200] was seen to be "composed of phenocrysts of basic plagioclase and augite, both occurring in crystalline groups in a ground-mass of lath-shaped plagioclase, augite, and iron-ores. Carbonates are also present in the ground-mass. It is a dolerite." A similar dyke is seen cutting the flagstones in the old quarry to the south of Muirshirlich poor-house.

PLEISTOCENE, INCLUDING GLACIAL.

So many interesting and important questions regarding the latest phases in the geological history of the British Isles depend for their solution upon a detailed study of the superficial deposits that steps have recently been taken to methodise more definitely than hitherto the systematic investigation of these deposits by the Geological Survey. In particular it seemed desirable to secure greater precision and uniformity in the noting and collecting of such organic remains as occur in the accumulations in question. The peat-mosses for example, which cover such large tracts in many parts of these islands, have never yet been systematically explored, with the view of ascertaining what evidence they and their associated sediments may yield as to former differences of climate. Accordingly some suggestions have been drawn up by MR. CLEMENT REID, who has devoted special attention to the subject. These have been circulated among the staff of the Survey for the information and guidance of the officers engaged in mapping the superficial deposits. As, however, they possess a general interest, and may be useful outside the ranks of the Survey, they are here inserted.

Mr. Reid on
the investi-
gation of
some recent
deposits.

The Post-glacial climatic changes that have occurred in Britain need more thorough investigation. The succession of cold and warm, or wet and dry, periods represented by the deposits above the Boulder Clay can be decided by an examination of the contents of the ancient peat-mosses and similar strata. It is necessary for this purpose to collect evidence from various districts and from various heights above the sea level.

Four main questions still remain unanswered :—

- 1st. What caused the dying away of the glaciers and ice sheets? Was it merely an increase of temperature, or was it the commencement of a period of dry cold, like that indicated by the loess of Central Europe?

- 2nd. After the disappearance of the ice and the incoming of a Temperate flora was there a general recurrence of cold conditions (but not glaciation) and re-entry of Arctic plants? Or are the deposits with a Temperate fauna and flora in the southern half of England equivalent to deposits lying below moraines in regions further north?
- 3rd. What was the relation of Palæolithic man and of the Pleistocene mammals to these climatic changes? What is the meaning of the break between Palæolithic and Neolithic? What physical and climatic changes did Palæolithic and Neolithic man respectively see in this country?
- 4th. What was the maximum amount of local submergence or elevation in Post-glacial times, and to what extent were the different islands connected?

Mr. Reid on the investigation of some recent deposits.

To answer these questions it is necessary systematically to examine the "submerged forests"; especially where in dock-excavations or such-like works several successive land-surfaces can be seen. Valuable results may be obtained by the study of sections through the deposits of silted-up lakes, especially when these lie in hollows in the Drift, and may therefore show a continuous series of strata from the passing-away of the ice to the present time. Peat-mosses also should be examined, and notes be taken of the size of any trees contained in them at considerable heights above the sea, especially of the former upward limit of the pine and oak.

In the collection of samples for further examination it should be borne in mind that unless the stratigraphical relations of the deposits are clear, it will scarcely be worth while to carry the material far or to undertake the slow work of pulling it to pieces and washing it. Among the samples needed, especially from the south-west of Ireland, are the bottom layers of a peat-moss, generally consisting of loamy or marly beds mixed with peat. These in England and Scotland often yield leaves of Arctic plants differing greatly from the Temperate flora of the overlying peat. Below the peat are sometimes found deposits of shell- or *Chara*-marl with *Megaceros*. These marls apparently yield relics of a flora less Arctic than that of the basal peat above; the fossils should therefore be kept separate, and a sample of the marl taken for washing for the smaller species.

If any Pleistocene mammal is found with the bones associated, it is desirable to save part of the matrix; for the climatic conditions under which certain of the larger mammals flourished is so little understood that we cannot at present point to their occurrence or non-occurrence as evidence of any change. Detached bones are of less importance, and may have been washed out of an older deposit.

A pound or two of carefully selected material properly examined will generally yield a clear indication of the origin of the deposit, the approximate climatic conditions, and whether the

Mr. Reid on
the investi-
gation of
some recent
deposits.

strata are likely to repay further examination. As, however, it is important that time and labour should not be spent on the collection of valueless samples, it may be pointed out that the thorough study of a selected locality, where the succession is clear, is far more important than the collection of miscellaneous samples over wide areas where no succession can be obtained. The ordinary fibre or moss-peat of a large peat-bog is of little interest, as it generally yields only the common wide-spread marsh and aquatic species still living in the country. Deposits filling a small silted-up channel or lake are of far more interest, for besides aquatic forms they yield remains of various dry-soil animals and plants which have fallen or been blown in from the adjoining banks; they are also more sandy or loamy, and therefore more easy to examine, and they contain fossils in better preservation. Great care, however, is needed to avoid confusion through landslips, or creep of older deposits over the peat. The specimens collected should be obtained after careful removal of the exposed surface, so as to eliminate any recent seeds or leaves which may have fallen on it.

Calcareous tufa contains relics of many perishable species which cannot be preserved under other conditions. It also, more often than other deposits, yields well-preserved plant-remains, such as give the clearest evidence of climate. Tufas of older date than the Neolithic Period should be carefully examined, and search should be made for hard tufas in old valleys or channels hidden under Glacial Drift.

Examples of the kind of investigations needed may be seen in MR. STRAHAN'S work on the "submerged-forests" of the Barry Docks (*Quart. Journ. Geol. Soc.* Vol. LII., p. 474, 1896); MR. BENNIE'S researches in the fauna and flora of the silted-up lakes in central Scotland (*Annual Reports of Geological Survey* for 1894, 1895, 1896); and the Report of the British Association Committee on the "Relation of Palæolithic Man to the Glacial Epoch," 1896.

In the following notice of the recent progress of the Survey among the Glacial and other Pleistocene deposits of the country, it will be most convenient to follow a geographical order, beginning with the southern and central counties of England, and then taking in succession Wales, Scotland, and Ireland.

Hampshire.
(Mr. Reid.)

In the Hampshire basin MR. REID has encountered only a continuation of the same deposits which have been described in previous Reports. These have all been decalcified, and yield no fossils except Palæolithic implements.

Oxfordshire.
(Mr. Blake.)

In Oxfordshire MR. J. H. BLAKE has definitely mapped the boundaries of superficial deposits of which at most only the existence had been previously indicated on the maps. Thus between Waterstock and Great Haseley, a few miles to the east of Oxford, he has traced an irregular plateau of high-level or hill gravel which measures two miles in length from east to west, with a breadth of a mile and a quarter at the east end. This gravel overlies the Gault, and consists chiefly of flints, quartz, and abundant rounded pieces of quartzite. In the central parts

where the deposit is thickest, it has been proved by well-sections Oxfordshire. to be from 10 to 12 feet in thickness. The highest portion of its (Mr. Blake.) surface is about 337 feet above Ordnance Datum, and from 150 to 160 feet above the level of the river Thame to the northward and westward of it. This outlier, which occupies the highest ground in its vicinity, and is independent of the present drainage system, shows in a marked manner the large amount of denudation that has taken place since its deposition.

In the areas north of the Charnwood Hills, and between the Trent and the Soar, which have been surveyed by MR. FOX-STRANGWAYS, not much boulder-clay or gravel has been met Leicester-shire and Derbyshire. (Mr. Fox-Strangways.) with. Patches of these deposits occur on many of the hill-tops, but they are generally thin, and, as in the Oxfordshire example just referred to, have evidently suffered extensive denudation. There appears to be more drift in the valley of the Soar than in that of the Trent. The alluvium of these rivers is extensive, as within a short distance the four large Midland streams—the Dove, the Derwent, the Soar, and the Trent—unite their waters. This deposit consists mainly of gravel, with but little clay. What clay there is seems to have been washed into the lower districts, which are liable to floods at the present time. The ground is intersected by innumerable old river-courses, which are interesting in that they show how frequently the streams have changed their position in quite recent times, and how the main stream has frequently blocked and diverted a tributary branch. On either side of this great valley there are extensive gravel terraces, which are probably of late glacial age. MR. DEELEY* calls them "interglacial"; but MR. FOX-STRANGWAYS has not as yet seen any evidence to lead him to suppose that glacial conditions were very marked after the deposition of these gravels.

North Staffordshire.

During the revision of the North Staffordshire coalfield (Mr. Lamplugh.) advantage has been taken of the opportunity to map also all the superficial deposits, as these had not previously been surveyed. By the recent increase of the staff in this district some progress has been made with the Drift survey, and various facts of considerable importance in regard to the glaciation of the Midland Counties have been brought to light. The area assigned to MR. LAMPLUGH has been examined by him between Uttoxeter and Leigh, and northwards to the villages of Upper Tean and Denstone, as well as eastwards to the valley of the Dove. The underlying formation of the greater part of this area is the Keuper Marl, which forms undulating ground that rises to somewhat over 500 feet above Ordnance Datum-level. On the north-west side a higher ridge of Keuper Sandstone and Bunter Pebblebeds reaches 739 feet in altitude. The Drift is spread scantily, in

* *Trans. Journ. Geol. Soc.*, vol. xlii., p. 467.

(Mr. Lamp-
lugh.)

patches of limited extent, over the solid rocks, being most fully developed in small plateaux on the higher ridges, while the slopes and the minor valleys usually either contain none or exhibit, at the most, a pebbly soil overlying the Marl to a depth of one or two feet. The lower flanks of the broader valleys, however, frequently present disconnected banks and terraces of stony loam and pebbly gravel which are not connected with the present conditions of erosion in the country, and are probably of fluvio-glacial origin.

The prevalent Drift of the higher ground is a red sandy loam, or more rarely, clay, containing numerous rounded quartzite and other pebbles derived from the Bunter (which frequently show the characteristic pittings) together with an occasional partially rounded fragment of hard sandstone probably derived from the Carboniferous rocks. The absence from most of the district of stones larger than about one foot in diameter and of any showing clear proof of glacial striation, together with the sandy character and local derivation of the material, seem to render the term "boulder-clay" somewhat inapplicable to this deposit. Evidence was obtained, however, that in spite of its abnormal composition and general resemblance to "rain-wash," the material is the local equivalent of the true boulder-clay of contiguous tracts, and has had a similar derivation from the moving mass of land-ice by which the whole country has been covered. The clearest proof of this was furnished by the presence of well-glaciated surfaces of Lower Keuper Sandstone at an elevation of 700 feet above O.D. (almost the highest ground in the neighbourhood), which were uncovered towards the end of last year in the large quarries at Hollington. These surfaces were directly overlain by the usual pebbly loam of the district, of rather unusual thickness (from 10 to 25 feet), and the direction of the striæ—W. 20° N. to E. 20° S.—shows that the movement of the ice has not been determined by the shape of the ground in the vicinity nor by the presence of the elevated Carboniferous Limestone tract of the Weaver Hills a few miles to the northward, but has been consequent upon the pressure of the great ice-sheet which was piled up over the lower ground to the westward and north-westward. As this is the only locality in the district where there is any rock sufficiently coherent to exhibit such traces of glaciation, it is fortunate that the quarry-sections should afford such opportune exposures.

Further evidence that the pebbly loam must be regarded as a local variety of the boulder-clay of the great ice-sheet is afforded by the fact that on the rising ground south of Uttoxeter, opposite to the great bend in the Dove Valley, where the river swerves from a southerly to an easterly course, the pebbly loam is suddenly replaced by a true till in which large subangular striated boulders of Carboniferous Limestone, toadstone, and other rocks are abundant. This material evidently indicates the path taken by the stream of ice which has descended the valley of the Dove; and MR. LAMPLUGH urges that its local development in relation to the more prevalent type of pebbly drift tells

strongly in favour of the land-ice as opposed to the marine theory (Mr. Lampugh.) of the origin of these drifts.

The absence from the greater part of the area examined of the large boulders of Lake District and other far-travelled rocks, which are so abundant in the country a few miles further to the westward and north-westward, is very noticeable, especially as the main ice-flow has been from that direction. It is probable that the lower layers of the western ice-sheet in which these boulders were mainly lodged were arrested by the steep Bunter escarpment, and that only the cleaner upper part of the mass, formed from the snowfall on the surface of the ice-sheet, moving as an upper current over the lower part, overrode this district. By this cause, also, we may explain the production of the drift-plateaux on the tops of the pre-existing ridges. These drifts seem to have been formed near the peripheral margin of the western ice-fields and close to their confluence with the eastern ice which brought the chalky drift into and across the main valley of the Trent above its junction with the Dove.

Immediately to the eastward of the Dove between Rochester and Uttoxeter, and also on the ridges due south of Uttoxeter, grey flints from the chalk occur rather plentifully in the glacial gravels, and are present in diminished numbers at lower levels in the gravels of similar age which extend westward from Uttoxeter to Bramshall, while scattered fragments of the same material were observed in the drift to the west and north of Stramshall two miles N.N.W. of Uttoxeter, but were not found farther to the northward or westward. The dispersal of these flints has probably been effected by the floods from the western margin of the eastern ice; and when the drifts of the country to the southward and eastward of the present area have been surveyed, it should be found possible to map out with considerable accuracy the limits of the ice-flows from the opposite sides of England.

In the higher reaches of the drainage-basin of the Dove, north of Ashbourne, the composition of the drift is totally different from that of the area above described, for it is made up almost entirely of extremely well-glaciated Carboniferous Limestone debris. These strongly-marked local variations in the character of the glacial deposits of contiguous districts not only negative the theory of the marine origin of the drifts of the Midlands, but also afford presumptive evidence that they have all been formed at about the same period, and by a single glaciation; and not, as sometimes supposed, by several periods of glaciation separated by mild intervals.

In the Keuper Marl district the glacial gravels are of some economic importance, since, being made up so largely of quartzite pebbles from the Bunter, they make useful road-metal and afford the only local supply of such material. The sands associated with the gravels are, similarly, the only local source of this substance for use in building. These gravels and sands are curiously sporadic in their distribution, occurring in small patches here and there on the highest ground, especially at the ends of

(Mr. Lamp-
ugh.)

hilly ridges, as well as in irregular banks in the valleys. Hence a careful survey of the whole area is necessary in mapping them. Their composition and mode of occurrence show that they are part and parcel of the general drift of the country, representing, in fact, the material of the pebbly loam assorted by the action of running water.

(Mr. Gibson
and Mr.
Wedd.)

Over the area of the North Staffordshire coal-field the drifts have been mapped by Mr. GIBSON, while to the west of it these deposits have been surveyed by Mr. WEDD. According to the latter observer, a line drawn from Madeley on the north-east to Market Drayton on the south-west roughly divides the district into a drift-covered area on the north-west side, and an almost driftless area on the south-east. The drift sweeps south-eastwards from the Cheshire plain for some distance up the flanks of the sandstone hills, and enters the valleys which open to the north-west. The same divisional line has been found by Mr. GIBSON to continue north-eastward to near Audley, between drift-covered ground to the west and driftless or nearly driftless ground to the east. The driftless portion is triangular in shape, the apex lying towards Audley. The east and west sides of the triangle coincide with the lines of the Bullhurst Large Fault and Apedale Fault, while the interior forms the highest ground to the west of the Potteries. Round Pipegate the Trias comes close to the surface, or so close to it as to show the thinness of the drift thereabouts.

In the drift-covered area around Woore and Bellaport Mr. WEDD finds a tumultuous assemblage of mounds and hillocks of sand or clay, of clay capped with sand, or of sand capped with clay. He believes that the majority of such hillocks, and especially when large or isolated, are in part or entirely composed of sand. About Pipegate, Woore, Madeley, and Betley large areas of continuous sand occur, while in other parts where sand is abundant it is found on the surface only in patches cropping out from under, or flanking, or capping hillocks, as in the neighbourhood of Bellaport. Two good examples of basins surrounded with drift-sand are to be seen in Betley Mere and Craddocks Moss, the former being a sheet of water lying in peat, and the latter a peat bog.

With the exception of small isolated patches of drift-sand and clay at Keele (575 above O.D.) and Acton, Mr. GIBSON finds the area to the east of the divisional line as far as the Trent Valley almost, if not entirely, free of drift, except in the valleys. Drift-clay with many erratics is found in the valley of the Lyme, while both clay and sand appear in the Trent Valley around Stoke-on-Trent and Bucknall.

It is noticeable that large boulders are more numerous in areas where drift-sands and clay are feebly developed. A large number of specimens of these boulders has been collected with a view to such a careful examination of them as might indicate their sources of derivation, and thus throw light on the movements of the ice over the north and centre of England. This collection of samples from the boulders has been studied by Mr. HARKER, who is well acquainted with the rocks of the Lake

District and the northern counties. He finds that though there (Mr. Harker.) are many boulders as to the origin of which no definite opinion can be expressed, a considerable number may be assigned with certainty, or with varying degrees of probability, to the Lake District of Cumberland. These include:—Eskdale granite in its various phases, distributed uniformly over the region; Buttermere granophyre, boulders of which are also widely and generally distributed; a rock with acicular crystals of augite closely resembling a certain local modification of the Carrock rock, common in the Hanchurch, Whitmore, and Willoughbridge districts; with less confidence, a rock very like parts of the Skiddaw granite, and another containing garnets which recalls the Threlkeld or St. John's mass. If these identifications be sustained, examples from all the principal intrusive masses of the Lake District are represented among the boulders of North Staffordshire. The Borrowdale volcanic series is likewise well represented, but chiefly by blocks from the fragmental rocks of the central mountains. The samples include breccias with angular fragments of pink rhyolite and scattered garnets; banded fine tuffs, and various other tuffs. Boulders of these materials are uniformly distributed over the area. The lavas appear to be less commonly represented, but one or two of the specimens may be andesites from the Lake District, and there are also some characteristic examples of the basic lavas of Borrowdale including basalts with porphyritic augites, streaky garnetiferous rocks, metamorphosed amygdaloidal basalts, the amygdules occupied by hornblende, pyrites, quartz, etc.; pink laminated and streaky rocks sometimes brecciated and resembling the Westmorland rhyolites.

Rocks from South Scotland are well represented on the high ground round Keele, Maer and Hanchurch. MR. HARKER remarks that these closely resemble the hornblende-bearing granites and tonalites of Galloway. As far as the evidence goes pieces from these Scottish rocks are less abundant on the Cheshire plain round Madeley, while Lake District rocks are there more abundant.

Rocks from Wales are probably represented by some compact felsitic boulders with white crust and evident flow-structures, sometimes containing blebs of quartz and corresponding very well with the rhyolitic lavas of Arenig. A grit resembling closely the unique rock of Ingleton is among a curious collection of large boulders near Shelton-under-Harley. Other grits are represented which, though possibly of Lake District origin, can be matched from the Carboniferous system in various localities.

The occurrence of fragments of marine shells in the drift of (Mr. Wedd.) North Staffordshire has been known for some time. Last year, however, MR. WEDD succeeded in obtaining these fossils from a number of new localities, and not only from the sands and gravels, but also from the boulder-clay at Dorrington and Betton. Many of his specimens are in a sufficiently good state of preservation to be determined. They have been examined by MR. CLEMENT REID, who recognises among them *Balanus*.

Turritella terebra (communis),* *Trophon*?, *Astarte sulcata*?
Cardium edule,* *Cardium* sp, *Cyprina*,* *Mya*,* *Mytilus*, *Tellina*
balthica.*

(Mr. George
 Barrow.)

On the east side of the North Staffordshire coalfield MR. BARROW has obtained good ice-striae, pointing from N.N.W. to S.S.E., a direction which agrees with the general trend of the transport of erratics in the Leek district. He has met with three examples of ice-worn pavements of grit under drift, but the direction of the striation on these was not satisfactorily preserved. The drift is thick on the top of the watersheds, and thins away rapidly towards the valleys. There is none on slopes of Bunter Sandstone even when these are gentle, and never much upon slopes of Carboniferous grits. Strata that throw out water seem to rid themselves of the drift with comparative rapidity, while on the other hand the drift tends to cling to the more impervious shales.

South Wales.

(Messrs.
 Strahan,
 Tiddeman,
 and Cantrill.)

In the *Annual Summary* for 1897 an indication was given of the general course of the ice-flow southwards from the Brecknock water-parting. It was there pointed out that a great split of the ice-sheet was effected by the Pennant scarp, a portion of the flow passing south-eastward down the Merthyr and Aberdare Valleys, while the remainder travelled south-westward down the Vales of Neath and Swansea. Further examination during last year has shown that this south-westerly flow was even larger than was expected, for it not only reached the sea in Swansea Bay, but over-rode many of the hills along the coast, and rose to a great height on the water-parting between the two vales. These statements are founded not only on the ascertained distribution of the boulders from the north side of the Carboniferous area, but on the discovery of a large number of glaciated rock-surfaces. The survey of the superficial deposits of the whole region is carried on by MESSRS. STRAHAN, TIDDEMAN, GIBSON, and CANTRILL. The following summary of last year's work has been drawn up by MR. STRAHAN.

The descriptions already given of the Drift of East Glamorgan-shire and Monmouthshire will apply equally to that of the area recently surveyed. At its source it is composed of Old Red Sandstone, and the blocks are subangular; as it passes over the shales of the Millstone Grit it becomes a stiff clay, and picks up vast numbers of blocks of grit, while on the Coal-measures the red tint gradually fades away and the proportion of Coal-measure boulders gradually increases, though Old Red Sandstone, Millstone Grit, and Limestone continue to be abundant right through to the sea. Near its source, moreover, it is generally a tough till, but towards the south it becomes more gravelly, and the boulders become more worn until they may nearly all be

* Forms marked with an asterisk are common.

described as well-rounded pebbles. In parts of the Vale of Neath, (Messrs. Strahan, Tiddeman, and Cantrill.) which was not only one of the main routes of the ice-flow, but also of the water escaping from the melting ice, the Drift assumes the form of a fluvatile gravel, not distinguishable in appearance from the gravel thrown down by the present river. The Glacial Gravels, however, differ from the post-glacial gravel-terraces in the fact that they have been heaped up in highly characteristic mounds and ridges, enclosing small peat-filled basins once occupied by meres. It is even thought possible by MR. GIBSON that they may once have dammed up parts of the Vale of Neath and given rise to large lakes, for in two places at least gravel-ridges still extend right across with the exception of a narrow notch cut by the river. This possibly is the origin of a deposit of sand which was found to extend to a depth of upwards of 40 feet in sinking the piers of the new railway-bridge a mile above Resolven.

The source and limits of a number of local ice-flows, tributary to the main Brecknock sheet, are no less clear than those of the main sheet itself. The deep cwms drained by Rheola and other neighbouring brooks, and by Crynant Brook in the Dulais Valley, are all occupied in their upper parts by great deposits of till, exposed to a depth of 60 feet, and in the last-named of more than 100 feet; the till is crammed with boulders, mostly well glaciated, but all of strictly local origin, derived in fact from the cliffs of the cwms themselves. But in their lower parts the till amalgamates with the Brecknock material and contains a gradually increasing proportion of boulders from that county. Seams of stratified gravel occur in this till, but are far from common. No fragments of marine shells have been seen hitherto in any of the South Wales glacial deposits.

The height to which the Glacial Drift extends seems limited only by that of the ground. Not only till with glaciated boulders, but numerous striated rock-surfaces have been noted by MR. CANTRILL at heights ranging up to 2,000 feet on the Old Red Sandstone dip-slopes. A little below the summit of Fan Fraith a small crag of pebbly grit is striated in a direction S. 35° E., which would lead to the Vale of Neath; at the foot of Fan Hir there are striæ pointing S. 30–50° E. towards the Tawe Fechan. Further west between the Giedd and Twrch striæ run parallel to those rivers, while on Fagl Bengam they occur at about 2,000 feet with a direction S. 10° W.

Further south (Pant Mawr) large patches of bare Millstone Grit show striations ranging to the S.W., but as the ice came within the guiding influence of the Vale of Swansea it took a more southerly course, and at Penwylt flowed directly down that valley in a direction S. 2–12° W. The Cribarth ridge, however, diverted a portion of this flow, as may be seen by numerous beautiful examples of rock-faces and cornices horizontally striated in a south-westerly direction. In the Giedd and Gwys valleys the flow resumed its southerly course.

Only one example of striated rock in place has been observed on the north side of the Brecknock Water-parting—viz., at

(Messrs.
Strahan,
Tiddeman,
and Cantrill.)

Pont Gihirych in the Crai Valley. The scratches run along the valley in a north-east and south-west direction, but whether up or down could not be determined. Evidence obtained by MR. CANTRILL this year, however, suggests the probability of the ice having crossed the water-parting from north to south. On the sides of the Tawynen Valley he has noted some large blocks of greenish-grey conglomeratic cornstone, the apparent source of which lies to the north-east of the Bwlch Pen Rhûdd, the pass connecting the Tawynen and Crai Valleys. In the upper part of the Crai Valley also similar blocks occur, which seem to have travelled southwards—that is, up the valley—from their outcrop.

Further examples of small ridges of morainic material have been met with in some of the cwms and at the foot of some of the precipices. In Cwm Gihirych an irregular mound of such material encloses a peat-flat, probably once a small lake; at the foot of the long straight escarpment of Fan Hir there is a conspicuous ridge, three-quarters of a mile in length and upwards of sixty feet in height. Several more or less indefinite mounds occur at various points below Fan Sir Gaer, two of which enclose lakes—Llyn y Fan Fawr and Llyn y Fan Fach.

Two instances of diversion of rivers by drift from their original courses have been observed by MR. CANTRILL. For example, the Byfre seems originally to have flowed uninterruptedly from its source on Fan Gihirych to the Tawe by way of Nant Byfre, but having been choked with drift about half way along its course, it now disappears down the swallow-hole known as Pwll Byfre, re-issuing from the cavern of Ffynnon Du, a mile and a quarter below Nant Byfre.

Within the limits of the Coal-field striae have been noted on Hir Fynydd, the water-parting between the Neath and Dulais Valleys, at heights of 1,400 and 980 feet, and on Resolven Mountain, by MR. GIBSON, at more than 1,000 feet; nearer Neath they occur on both sides of the Neath Valley in a position which indicates that that deep depression was filled with ice, probably to overflowing, while the hill of Coed yr Iarll, and others near Briton Ferry, display so many glaciated surfaces as to show that they were completely overridden. Boulders of Millstone Grit, moreover, scattered over high ground indicate that the ice extended further than can be proved by the accidental preservation of striated rock-surfaces. The water-parting between the Dulais and Swansea Vale seems to have been overridden also, at least in its lower parts, for there is a large area of glaciated rock on its crest (nearly 1200 feet above the sea), at the northern foot of Mynydd March Hywel, the striae ranging W. 30°–35° S., as though the ice had overflowed from the Dulais into the Tawe at this point. Last year similar evidence was obtained of the ice having overflowed from the Vale of Neath into Fforch Dwm, and some striae, noted by MR. GIBSON in the stream at Hendre Owenfach as having the unusual direction of N.W.-S.E., may be due to some such local overflow. Near this spot he observed also a beautifully-glaciated boulder of Pennant measuring 14 feet × 9 feet × 3 feet.

A good example of a large transported mass of Millstone Grit occurs on the Neath and Brecon Railway two miles south of Penwyllt. The cutting intersects a small but conspicuous conical eminence on the hill-side, and shows that it consists of slightly broken Millstone Grit in the upper part and of till crowded with well-glaciated blocks of Old Red Sandstone, Millstone Grit, and limestone in the lower part. This is the third example met with in South Wales, the others being the mass of grit exposed in the Sirhowy reservoir and the crag in the Rhondda-fach Valley known as Castell Nos. The last-named, however, is of uncertain origin. (Messrs. Strahan, Tiddeman, and Cantrill.)

In the Vale of Glamorgan, to the south of the Coal-field, MR. CANTRILL finds characteristic mounds and hollows of gravelly drift east of Welsh St. Donats, and in the valley of the Dawen as far south as Cowbridge. The boulders are chiefly of Coal Measure origin, but a few of Old Red Sandstone occur. Two small outliers of fine gravel and sand near St. Mary Church contain also numerous sub-angular fragments of flint.

MR. TIDDEMAN in the adjoining area to the west has mapped a patch of Boulder-clay about a square mile in extent south of Kenfig Pool, and others both clayey and gravelly in the valley traversed by the Great Western Railway between Stormy and Pyle. Another patch in the Ewenny valley, and extending towards that of the Ogmore, consists of reddish clay with small stones; the greater part of the boulders are Pennant rock, but yellow partly-rolled flints are not uncommon. The clays when most free from stones have been much used for making pots, and are reported to have been worked from Roman times.

The clay is covered with gravels which have a more or less flat surface, and which are not easily distinguished from river-gravels. It is thought by MR. TIDDEMAN that if they were of glacial age and had the moundy outline which characterises the gravels near Llanilid, they must have been subsequently levelled by either river or sea. The latter supposition would imply a submergence in this district of 50 to 100 feet, of which no sufficient evidence has yet been forthcoming.

Isle of Man.

Though the Geological Survey of the Isle of Man has been completed, important information has recently been received (Mr. Lampugh.) regarding the latest (No. 6) of the series of deep borings made in the north of the Isle of Man, which has revealed some points of exceptional interest in relation to the drifts of the island. This boring, the site of which is near the Point of Ayre Lighthouse, only a few feet above high-water mark, was sunk to a depth of 920 feet to prove the extent of the saliferous Keuper Marls which had been discovered in a previous boring. The Glacial series was found to be of unusual thickness, apparently descending to between 470 and 500 feet below sea-level. To the courtesy of MR. J. TODD, under whose supervision the difficult task of

(Mr. Lamp-
ugh.)

carrying the boring through the drifts was successfully accomplished, we are indebted for a set of specimens from various depths, which have been washed, sifted, and examined.

The following is a condensed account of the section based on this examination, and on the details supplied by MR. TODD:—

Shingle : Raised beach	- - - - -	16 feet.
Sand and gravel : partly of marine origin, but re-arranged by glacial agencies	- - - - -	97 „
Stony sandy clay, with beds of warp, &c., like that of the cliff sections = boulder-clay series, incorporating marine material	- - - - -	102 „
Muddy sand, silt and gravel, full of shells, one seam containing chiefly <i>Rhynchonella psittacea</i> ; many of the pebbles coated with nullipora, &c. = a marine deposit	- - - - -	25 „
Reddish sand and gravel, largely made up from the washing of the Triassic rocks of the vicinity; with only a few much-worn shell fragments. A boulder 8 inches in diameter passed through near the base	- - - - -	123 „
Red stony clay, composed of crushed Keuper Marl, with a few far-travelled stones = Lower Boulder-clay	- - - - -	65 „
Reconstructed red marl, with a few subangular erratic pebbles 25 feet above base = glaciated top of Keuper Marl?	- - - - -	70 „
Keuper Marl, disturbed in the upper part, with many bands of salt below 600 feet	- - - - -	422 „
To bottom	- - - - -	920 feet.

The new points brought out by this section are the depth to which the glacial material descends below sea-level; the presence of a local boulder-clay underlying the stratified drifts, made up almost entirely of material derived from the subjacent rock; and the existence between boulder-clays of a thick band having all the characteristics of a true sea bottom, differing from anything recognised in the former boring sections.

Whether the shelly deposit represents a true marine horizon in the glacial series, or is a large transported remnant of the early glacial sea-bottom, cannot, of course, from the nature of the evidence be definitely decided. At the base of the series it is also difficult to determine exactly the limits of the drift, as masses of marl seem to be intercalated with bands in which extraneous pebbles have been mingled with crushed marl.

Isle of Arran.

(Mr. Gunn.)

The survey of the northern half of Arran has brought to light many proofs that this island was glaciated by the vast mass of ice which moved southwards in the basin of the Firth of Clyde. In the north-west part of the island MR. GUNN has met with numerous striated rock-surfaces in which the general trend of the striæ is towards S. 10°—20° W. A particularly fine example of a grooved and polished surface of schist may be seen by the roadside immediately south of Whitefarland.

To the east of Auchencar numerous ridges of boulder-clay, or (Mr. Gunn.) drumlins, run in the general direction of the great glaciation. Relics of a later and more local glaciation also occur in nearly all the valleys in the shape of moraines. They are conspicuous in the valleys at the head of the north Sannox stream, on the north side of Castle Abhail.

In the valley of the Machrie Water about Monyquill and Glaister, and also up the Machrie Burn, mounds of detritus occur which at a distance might be mistaken for moraines, but which when closely examined are found to consist of washed sand and gravel. They are therefore more of the nature of eskers or kames.

Argyllshire.

The glaciation of the Oban district has been further examined by MR. SYMES. The general direction in which, as shown by the striae on the rocks, the ice has here moved has been from east to west, but every glen, valley, and fiord has a distinct local glaciation. Thus, while the glen at Kilninver, eight miles south of Oban, trends in a direction towards N. 27° W., and has its striae directed to the same quarter, on the south side of the watershed, where the drainage into Melfort Loch runs in a southerly direction, the ice striae point to S. 20° W. All the minor striae then gradually curve westward into the general glaciation as they approach the seaboard. Oban district.
(Mr. Symes.)

The boulder clay extends over the district as a thin deposit crowded with huge erratic blocks transported from the east, but it attains a considerable thickness in the glens, where it has been subsequently eroded by streams, and its detritus has been re-arranged in gravel terraces. Some conspicuous examples of such terraces may be observed along the north shore of Loch Scamadale, nine miles south-south-east of Oban. They are composed of stratified sands and gravels, and rise 10 and 31 feet above the loch, which is 221 feet above sea-level. They continue along the valley below the lake as far as Euchar Bridge, sinking gently with the general slope of the river. Associated with these terraces are more recent gravel deposits formed out of the terraces by the action of the stream.

Further eastward in the mountainous district, of which Ben Cruachan is the most conspicuous feature, the mapping of the glacial deposits has been advanced by MR. KYNASTON, who has met with a continuance of the same general features as have already been described in former *Reports*. In the part of the area near Dalmally a large portion of the more low-lying ground is covered with thick accumulations of moraine-drift from the coalescence of the large glaciers that flowed down Glen Orchy and Glen Lochy. Loch Awe
and Loch
Etive. (Mr.
Kynaston.)

The Glen Etive area furnishes further ample evidence of the later valley glaciers in the form of morainic material. The River Etive and its tributaries, however, have now eroded their channels, sometimes deeply into the underlying rock, while the morainic

Loch Awe
and Loch
Etive. (Mr.
Kynaston.)

material has been to a great extent rearranged and transported to lower levels. The unusually large size of many of the detrital fans at the mouths of the burns (*e.g.*, along the shore of the upper part of Loch Etive), and the coarseness of the material of which they consist, are very striking. But this is perhaps not surprising when we consider the great capacity for the breaking-down and transportation of material possessed by the torrents during flood-time, and the enormous quantity of more or less loose material at their disposal. The work of these mountain-streams, moreover, is largely assisted by small tributaries, which run over bare rock pitching at a high angle. Down these, and down the numerous "scree-gullies" and "stone-shoots" lining the mountain-sides, the water is poured in torrential cascades during times of heavy rainfall, pushing on and piling up enormous boulders as though they were small pebbles.

In connection with the effects of running water on the glacial deposits of this region, MR. KYNASTON has reported his observations on recent changes of the river courses, to which reference may be most conveniently made here. He notes an alteration in the channels of such rivers as the Etive, the Kinglass, and the Orchy, which is constantly going on from year to year, where they come out into the lower and wider portions of the valleys. The amount of this alteration can be appreciated by carefully comparing the six-inch Ordnance maps, published more than thirty years ago, with the present course of the rivers and distribution of the alluvial plains. Terraces and alluvial tracts are seen to have been extensively cut away in some places, while fresh alluvium is being laid down in others. The cutting away of terraces, &c., is naturally greatest at the convex side of a bend, and is doubtless due to the increased erosive and transporting power possessed by the river during flood-time, when this action may actually be observed. Such rivers as these rise rapidly, owing to the rapidity with which their tributaries from the surrounding high ground carry off the water from a large area, hence they become exceedingly powerful agents of denudation during heavy rainfall. While mapping the alluvium near the mouth of the Etive, MR. KYNASTON ascertained that the bank of the river along the outer side of a bend had been cut away at the rate of a foot or more per annum.

Loch Eil
District. (Mr.
Grant-
Wilson.)

During the past year MR. GRANT-WILSON was able to complete the mapping of the chief portion of the drift deposits within the basin of Loch Eil. These are entirely composed of morainic materials, and both from the size of the moraines, the manner in which they are grouped, and the extent of ground over which they are distributed, they point to the movement of a large sheet of ice from the west. The striae in the basin of Loch Eil point towards E.S.E.* and show the direction of the ice-flow. On the north side of the loch the moraines are found up to a height of 2,256 feet on the Druim Fada Hills, and pass over the watershed into Glen Loy. On the south side they do not reach above 1,750 feet,

* *Summary of Progress* for 1897, p. 146.

but they pass over the intervening col into the valley of Strone-craggan. Viewed from a distance these drift deposits on both sides of Loch Eil exhibit lines of terraces on a large scale.

Loch Eil
District. (Mr.
Grant-
Wilson.)

With the exception of a few knolls of rock the whole of the low ground between Banavie and the rivers Spean and Lochy is occupied with moraine drift, and this deposit covers the lower slopes of Ben Nevis up to a height of 1,500 feet.

The greater number of these moraine mounds are composed of fine material. Thus, three miles from Spean Bridge, the face of a large ballast bank on the railway shows 20 feet of false bedded sand and gravel resting on 70 feet of fine gravelly moraine detritus. A mile further south and opposite the Creag Aoile a section may be seen of about 100 feet of fine sharp sand with glacial silt-bands and traces of fragments of decomposing shells.

The wide extent and great depth of these moraines prove how large must have been the body of ice that moved down upon this low ground from the west of Loch Eil, Loch Arkaig, and Glen Albyn. If the valleys to the south and east were at the same time free from ice in their lower reaches, the northern ice might have dammed back the waters of the eastern glens in the manner supposed by MR. JAMIESON in explanation of the "Parallel Roads" of Glen Spean.

From Blairour to the Falls of Mucomir, on both sides of the River Spean, numerous fragments of high-level terraces are to be seen. A cutting on the Fort Augustus railway passes through one of these and shows 20 feet of fine brown glacial silt resting upon blue silt with gravel on the top. These terraces rise up to 270 feet above sea-level, and lie at least 100 feet above the present level of the river. From their position and contents they could not have been deposited by the River Spean. They appear to have been formed at the period when the bottom of Glen Albyn was still filled with ice which ponded back the water above. They doubtless point to a decreasing stage of the glacier which once filled the Great Glen. When this ice-barrier from the north melted, the River Spean would have free scope to sweep away the glacial detritus in its path and to begin the erosion of the rocky gorge in which it is now confined.

Within the moraine area, which stretches from the foot of the Ben Nevis range to the River Lochy, the sites of two large vanished lochs have been mapped. The larger of them lies on the watershed between the rivers Lundy and Loin, and covers at least a square mile. With the exception of two small remaining tarns the bottom is now quite dry, flat, and about 430 feet above sea-level. The deposits which cover its bottom so far as can be seen are composed of fine glacial silt and sand. The lake was entirely surrounded by moraines. The site of the other sheet of water lies to the north-east of New Inverlochy Castle. A stream flows sluggishly along its length, and numerous sections show its bottom to be filled with glacial silt and sand. Its average level above the sea is 80 feet.

Island of
Jura. (Mr.
Wilkinson.)

The glacial phenomena of the mainland of Argyllshire are prolonged into the islands that flank the coast, some of which were high enough to nourish their own independent glaciers when the great ice-sheet had sufficiently diminished. In Jura, MR. WILKINSON has found evidence of the march of the mainland-ice across even that lofty island. Along the coast indeed, the striæ indicate that the ice was deflected in its lower portions and moved irregularly along the shore-line. But on the higher ground some large and fine examples of grooved, polished and striated surfaces, which after a passing shower has rendered them wet, reflect the sun's rays with most dazzling effect, demonstrate that over the backbone of the island the ice moved from east to west, varying a little to the north.

Boulder-clay, which has been plentifully deposited, is found banked against the sides of the higher hills and slopes down to the Sound of Jura. Many sections show it to be a stiff clay, often red in colour, with abundant well-rounded and sometimes striated boulders, among which quartzite, epidiorite, dolerite, red sandstone, red porphyry, and andesite are the most common.

The higher corries and glens of the island evidently nursed glaciers after the disappearance of the ice-sheet, for moraine material is abundant there, sometimes even stretching down to the lower valleys.

Connected with at least the later stages of the Ice Age are the Raised Beaches, which form so prominent a feature in the scenery of the west coast of Scotland. The east side of Jura presents a succession of these terraces all along the coast-line from Ardfin in the south of the island to north of Ardlussa House. They lie at various levels, but rarely rise above the hundred-foot contour-line.

It is on the west side of the island, however, that the raised beaches attain their most striking development. They have not yet been completely mapped there, and an account of them is reserved for a future *Summary*.

Perthshire.

Strath-
gartney,
Perthshire.
(Mr. Cunn-
ingham-Craig.)

In the Perthshire district, surveyed last year by MR. CUNNINGHAM-CRAIG, which included the basin of Loch Katrine, he found the direction of flow of the ice-sheet to be on the whole towards the south east. He succeeded in establishing this point by obtaining a large number of observations of striæ on quartz-veins even up to the highest hill-tops. He also met with plentiful evidence of later or local glaciation, each glen having its groups of moraines.

Aberdeenshire.

Braemar.
(Mr.
Cunningham-
Craig.)

In the area of Braemar, surveyed last year by MR. CUNNINGHAM-CRAIG, the glacial phenomena were traced across the ground between the River Dee and the flanks of the Cairngorm Mountains.

He could rarely detect any rock-striae that would show the direction of the ice movement; they are scarce and never clear, but the transportation of erratic blocks serves to give a general idea of the flow of the ice-sheet. The best example of this evidence is the occurrence of blocks of the Glen Derry diorite on the hillside above Allanmore, at a distance of more than six miles to the south-east of the parent mass. These blocks could not have been brought to their present position by the later or local glaciation, but must have been transported by the ice-sheet over ridges nearly 3,000 feet in height.

Braemar
(Mr.
Cunningham-
Craig.)

An interesting case of diverted drainage is afforded by Glen Slugain. The upper part of this wide and deep valley contains a mere rivulet of water, which for considerable distances finds its way underneath accumulations of quartzite scree. At the head of the glen a flat expanse of ground is covered with drift and morainic material reaching to the River Quoich, which makes a sharp turn to the westward at this point. It seems that what are now the head-waters of the Quoich used to flow down Glen Slugain, but that during the glaciation the ice descending from the plateau of Beinn a' Bhuidr ploughed out the wide east-and-west hollow to the south of that mountain, and with part of the removed material blocked the Slugain valley. The waters of the Quoich were thus enabled to cut back along the hollow south of Beinn a' Bhuidr and "behead" the Slugain burn.

At Lochan a' Bhata, situated to the eastward of a col between Glen Dubh and Glen Derry, an interesting deposit has been formed. A flat triangular mass of coarse detritus contains the lochan, the apex terminating in a rocky gorge, while the base presents a very steep scree like face to the glen beneath. This deposit can only be accounted for on the supposition that the main glen (Glen Dubh) was filled by a glacier, against the side of which, or more probably in a small glacial lake formed between the glacier and the hillside, the fan-like mass of material was deposited. The material forming the deposit was brought down by the small burn, which finally occupied and kept open the shallow depression in its delta, which is now filled by the Lochan a' Bhata.

Inverness-shire.

A full account of the remarkable terraces of Strathspey, by MR. HINXMAN, was given in last *Summary of Progress*. Little of any importance has been met with since to add to that account of the glacial history of this great Highland river. The high level terraces of fluvio-glacial gravel have been found to continue up Glen Truim as far south as Crubinnmore, and to rise to a height of 1,020 feet. On the southern slopes of the Monadhliath the moraines that mark the levels of the valley-glaciers are succeeded in many places by hard grey till of considerable thickness.

Strathspey.
(Mr.
Hinxman.)

Ross-shire.

Beauly.
(Mr.
Hinxman.)

In the Beauly area, to which MR. HINXMAN was transferred for part of the season, he found the hill-slopes and higher parts of the valleys that descend to the head of the Firth to be covered to a great depth with boulder-clay. Thus along the course of the Allt Goibhre sections can be seen showing 80-100 feet of sandy clay. The included stones are mostly of local origin, but there are also many boulders of granite, pegmatite, hornblende-schist, and hornblende-rock, derived from ground further to the west or north-west. Large boulders of a beautiful augen-gneiss and red granite occur in great numbers on the ridge of the Black Isle at Balvaird, near Tarradale. These have been derived from some of the bands of that rock which have been detected among the mountains of eastern Ross-shire.

The 100-feet raised beach forms a wide and conspicuous feature at the head of the Beauly Firth between Tomich and Tarradale House, and its landward margin is clearly defined along the slopes of Clashdorran and Aultavaich. At Muir of Ord it merges into the fluvio-glacial gravels that cover the col between the heads of the Beauly and Cromarty Firths. The beach has been greatly denuded between Tarradale Mains and Redcastle, and only appears in a fragmentary condition, but it can be seen in section capping the sandstone in Redcastle quarry.

Loch
Luichart and
Black Isle.
(Mr. Peach.)

Among the high grounds already referred to as having been surveyed by MESSRS. PEACH, HORNE, and POCOCK in the region of Fannich Forest and Loch Luichart, as well as in the lowland of Easter Ross, additional particulars have been obtained regarding the glaciation of that part of Scotland. So thick did the ice remain in many of the higher inland valleys, that there is often difficulty in detecting any satisfactory evidence of the earlier phases of the glacial period. MR. PEACH in the Loch Luichart district last year was unable to find any such evidence. Only on the low ground of the Black Isle in Easter Ross did he come upon undoubted traces of the earlier glaciation. In a sandstone quarry near the village of Conon, striae were observed by him which pointed E. 20° N. and passed underneath a tough boulder-clay or till, full of well-glaciated blocks of sandstone, Highland schist, augen-gneiss, granite, &c. Above this deposit lies a considerable thickness of looser sandy morainic débris, in which occur large angular blocks of sandstone and occasional boulders of schist, augen-gneiss, &c. Similar phenomena were met with in several places in that part of the region. The striae and till are attributed by MR. PEACH to the earlier glaciation, while the overlying morainic material is regarded by him as the product of a large glacier which issued from the Conon Valley and spread out upon the Black Isle at the time when the ice reached its greatest extension during the period of the later glaciation. The concentric arrangement of the moraines which cover most of the slope of the Black Isle right up to its crest opposite Dingwall is very conspicuous.

In the mountainous area surveyed by MR. PEACH to the west,

the phenomena which he observed he could only regard as belonging to the later glaciation. The striæ, the disposition of the lateral moraines, and the distribution of the carried blocks show that during the greatest extension of the later glaciers a glacier or ice-sheet moved across the watersheds from Glen Fhioding and from Strath Carron into the valley of the Bran, where it received tributary ice across the high cols from the Fannich Valley, swept round Sgurr a Mhullin, leaving the top of that mountain as a "nunatak" or islet, wheeled upon itself on reaching the neighbourhood of Loch Luichart, and, after combining with the main body of ice from Fannich and the Blackwater Valley, issued from the Highlands by the Conon Valley and spread out upon the Black Isle. The blocks of augen-gneiss from Inchbae and Loch Luichart afford excellent material for following the track of the lower part of this combined glacier.

Loch
Luichart and
Black Isle.
(Mr. Peach.)

The disposition of the terraces of lateral moraine round the hill-tops to the south of the head of Loch Luichart indicates the successive stages in the decrease of this glacier or ice-sheet when the smaller hills (some of which, however, reach a height of more than 1,800 feet) began to appear above its surface as scattered islets. The terraced moraines on the valley-slopes and the succession of terminal moraines along their bottoms, and which bar their streams, plainly mark pauses in the general decrease of the ice, which eventually disappeared leaving the corrie-moraines as its last trace. The terraced moraines are well seen in the neighbourhood of Loch Luichart, but the finest display of them is to be found round the northern flanks of Sgurr a Mhullin, as seen from the railway near Achault, where they appear as a giant staircase to that fine mountain. The terminal moraines are well shown along the line of the railway from Achterneed near Strath Peffer to Achnasheen, though they are most conspicuously displayed between Garve and Loch Luichart Stations.

On the part of the Black Isle, and on the lower portion of the Valley of the Conon, surveyed by MR. PEACH, he found the 100-foot beach to be well marked. Its presence there shows that the ice had retreated inland from the shore either before or during the time when the materials of the terrace were deposited. In the Torridon and Applecross regions of the West Coast, as indicated in previous Reports, the ice continued to descend to the sea long after the time of the 100-foot terrace. In the Black Isle the bluff bounding the upper limit of this terrace truncates the successive concentric moraines. The original flat surface of the terrace is now much furrowed and made irregular by denudation. Sections are thus exposed which show the materials of the terrace to consist chiefly of fine sand and gravel, with sometimes considerable tracts of a finely laminated fawn-coloured clay. Both the fifty-feet and the twenty-five feet raised beaches are well developed on the shores of the Cromarty Firth and along the banks of the River Conon. The deposits consist of sand and clays containing shells, such as cockle, mussel, periwinkle

Loch
Luichart and
Black Isle.
(Mr. Peach.)

and other estuarine and littoral species common on our present shore. Besides the terrace of the twenty-five feet beach, there are indications of several smaller fragmentary terraces between the fifty-feet raised beach and the present sea-level, which can only be followed for short distances, but which suffice to prove that the movement of elevation was intermittent, and extended over a considerable period of time. Several well-marked rock-basins occur in the area examined by MR. PEACH, the finest of which are occupied by Loch Luichart, Loch Coulin, and Loch Garve.

Fannich
Forest. (Mr.
Horne.)

In the district of Fannich Forest, surveyed by MR. HORNE, few striated surfaces were observed on the southern slopes of the Fannich range. A thick covering of drift fills the deep valleys that penetrate the chain, and it forms a gentle slope along the north side of the loch. Several finely striated surfaces, however, were detected at high levels, as, for instance, on the crag at the head of Allt Choire Bhig (about 2,500 feet), where the direction of the striae is S. 22° E.; on the spur that forms the southern projection from Meallan Rairigidh (between 1,500 and 1,750 feet), where the trend is S. 13°–20° E.; and on the southern slopes of An Coileachan (between the 2,250 and 2,500 feet levels), where the striae point S. 14°–18° E.

These striated surfaces lie in the eastern portion of the Fannich mountains, and were evidently produced during a period when his mass of high ground formed a centre of dispersion for the ice. There can be no doubt that, as has already been stated, the ice which radiated from the southern portion of the Fannich range crossed Loch Fannich, and overspreading the ridge to the south of that sheet of water, passed into Strath Bran. Quite recently a forest path has been made across this dividing ridge, leading from Achanalt to Cabuie. At various points on the crest of the ridge finely striated surfaces have been laid bare in pit-holes opened in the drift, where the striae point in a S.S.E. direction. The Fannich range runs in an east and west direction for a distance of seven miles, and all the main peaks along the range rise above 3,000 feet. It is obvious that the mass of ice flowing southwards towards Strath Bran must have been considerable, and not improbably furnished the ice-dam that gave rise to the lake-terraces at Achnasheen.

East of Fannich Lodge a deposit of boulder-clay is covered by moraines, while groups of moraines extend westwards to the head of the loch and up the main valleys. No great moraines of recession, or corrie-moraines on a large scale, occur in the ground surveyed by MR. HORNE.

Black Isle.
(Mr. Horne.)

In the portion of the Black Isle mapped by MR. HORNE, which lay to the east of the ground surveyed by MR. PEACH, various striae were observed which show that the ice there moved in an easterly and E.N.E. direction. The following examples may suffice to indicate the movement—(1) on the hill slope half a mile west of Fortrose E. 6°–14° N.; (2) near Belmaduthy E. 10° N.; (3) near Colbokie, on the west slope of the Black Isle, E. 18° N.

The evidence of the striated rock surfaces is confirmed by that supplied by the boulders in the drift. Though the greater part of the Black Isle is formed of Old Red Sandstone, a large proportion of the stones in the drift consists of crystalline schists, granite, and other igneous rocks, which have been derived mainly from the high grounds lying to the west. Large erratics of rocks foreign to the Black Isle are of common occurrence, consisting of augen-gneiss or foliated granite, epidiorite, hornblende-schist, and massive grey granite. Attention has been directed to the distribution of these boulders by various local observers in the north of Scotland, and in particular to that of the boulders of foliated granite resembling the Inchbae rock west of Garve, already referred to in the notice of MR. PEACH's observations, while blocks of this peculiar rock are found in the southern portion of the Black Isle near Tarradale. They become more plentiful northwards in the direction of the Millbuie ridge. If no other locality than Inchbae has been the parent source of these boulders, then the Conan Glacier probably reached the southern margin of the Beaully Firth.

Boulder-clay is distributed over the eastern portion of the Black Isle, where between Belmaduthy and Raddery it forms a gentle slope, but over the western portion extending from Colbokie southwards to Tore a remarkable series of moraines may be observed to form prominent ridges with lochans or marshy hollows between them. In the various pit-sections in these moraines the material is composed of sand and gravel, with an admixture of clay; the stones of foreign origin being associated with large subangular blocks or masses of the underlying yellow sandstone. As these moraines are traced eastwards in the direction of Munlochy they gradually merge into ridges of sand and gravel.

In the Fortrose region the 100 feet, 50 feet, and 25 feet raised beaches are admirably displayed. They may be followed at intervals all round the southern portion of the Black Isle to Tarradale.

The glaciation at the east end of Loch Fannich, and also that of Beinn nan Ramh to the south-west of that sheet of water, were examined last year by MR. POCOCK. In the first of these two tracts he obtained a fairly complete set of observations of rock-striae in illustration of the movement of the ice at different stages of the Glacial period, but very few were found in the Ben Ramh area. The finest examples can be seen on the quartzose Moine-schists by the roadside at the foot of Loch Fannich, and at the top of Aultdearg Wood. The greater number of striae in the area towards Loch Luichart point a few degrees south of east. But an older set, somewhat obscure, is indicated by cross hatches, obtained at a height of 1,500 feet, on the shoulder of Ben Dearg. These point in a southerly direction, and may belong to the period of the lowland boulder-clay. The easterly striae indicate an epoch of intense glaciation, during which the top of Ben Ramh, with the more formidable barrier of Ben Fionn behind it, served to divide two ice streams, one of

Loch Fannich
and Beinn
nan Ramh
district (Mr.
Pocock.)

Loch Fannich
and Beinn
nan Ramh
district. (Mr.
Pocock).

which has been already alluded to as having moved into Strath Bran, while the other crossed the peaty plateau on the west in the direction of Loch Maree.

Beyond the east end of the Fannich range striae were obtained on the summit of Ben Dearg at a height of more than 2,000 feet, showing that the ice from the north side of the Fannich ridge crossed the hill-top without deflection. The ice from the south side of that ridge, instead of following the course of the Grudie River, passed straight over Càrn na Bèiste at a height of 1,680 feet, and, descending the east side, crossed the Grudie Valley at an oblique angle. These two streams must have coalesced on the lower ground east of Ben Aigean.

A later stage of glaciation is indicated by repeated instances of cross hatching in the striae, found in the lower ground of the Loch Luichart district, in which a newer set of striae, following the course of the valleys, obliterates the older set pointing across them to the east. At this stage the ice of Loch Fannich passed round the north side of Càrn na Bèiste along the course of the Grudie River, while tributary streams from the north descended the valleys on either side of Ben Dearg.

Moraines of recession, belonging to the last stages of the Glacial period, are fairly common in the Grudie Valley, but they are low and inconspicuous, being, probably, an old series that has undergone much denudation. Boulders of flaky garnetiferous gneiss, strewn over the tops of these moraines, have come from the rocks which crop out near the head of Loch Fannich.

A far more conspicuous set of moraines occurs in the valley between Ben Aigean and Ben Dearg. One of these, which is upwards of 20 feet high, extends across the mouth of the valley for a distance of about a mile; another curves round the great corrie of Ben Aigean, while a third set runs up the valley in a direction more or less parallel to the Ben Aigean cliff. Moraines are found also on the west side of Ben Ramh, with occasional boulders of garnetiferous flaky gneiss, derived from the hill top, while in the Stratheromble Valley on the south side of the hill another group occurs which has been formed by the corrie glaciers of Ben Fionn.

Caithness.

(Mr. Pocock.) In the Braemore district, Caithness, surveyed last year by Mr. Pocock, no facts of special interest were observed in the glaciation of this county. The greater part of the ground examined, with the exception of the Morven Hills, is covered by boulder-clay of the usual type, consisting of subangular boulders, striated in the direction of the ice movement, and set in a matrix of tough clay, which is red and sandy where it lies on the Old Red Sandstone, but becomes grey and granitic where it rests on granite. The rock-striae, as well as the transported boulders, indicate an eastward movement of the ice. The shelly boulder-clay hardly comes within the area recently surveyed, but a blue boulder-clay similar to that from which ROBERT DICK obtained

marine shells in the Dunbeath Water occurs as far west as (Mr. Pocock.) Pollroy. Moraines belonging to the later phases of glaciation are not common, the wide open strath to the north of Morven being unfavourable to their formation. They were observed in only two places, viz., a short distance above Braemore, and two miles down the Berriedale Water from Goberniesgeach.

Island of Skye.

The progress of MR. HARKER'S mapping in and about the Cuillin Hills, and on the moorland ground farther north, has given more detailed information concerning the glaciation of this central part of Skye, which, as already pointed out in former Reports, was due wholly to local glaciers. At the epoch of maximum glaciation only the highest summits of the Cuillins stood above the ice. This is true also of Blaven, and probably of the Red Hills, though the crumbling granite of which these latter are built is not fitted to preserve the evidences of glaciation. The main range of the Cuillins, with its prolongation north-eastward and eastward to Sgùrr nan Gilleann, was then, as now, a line of divide; but elsewhere among the mountains the ice did not always follow the present drainage-lines. The mountain area is divided by a broad double strath, formed by the Sligachan Valley running northward and the Camasunary Valley running southward, with a low watershed (250 feet) between them. The Sligachan River is fed chiefly from the west, especially from Harta Corrie, which drains the interior of the northern part of the Cuillins; the Camasunary River is fed chiefly from the east, from the corries between Marsco and Blaven. In Glacial times, however, the great glacier from Harta Corrie divided, part going northward and part southward, over Druim an Eighne and along the eastern side of Coire Riabhach. Similarly the ice from the eastern mountains divided, part going towards Sligachan and part towards Camasunary. The low watershed was thus at once the meeting-place of two ice-streams from west and east, and the parting of two streams to north and south. These must both have been of considerable magnitude. The northward-moving glacier, on reaching the mouth of the valley at Sligachan, spread out like a fan. On the left hand it became confluent with the smaller glaciers from the northern corries of the Cuillins—Coir' a' Bhasteir and Fionn Choire—and the united stream flowed westward into the upper part of Glen Brittle, over-riding the pass (1,150 feet) north of Bruach na Frithe, and leaving striæ directed westward on the ridge of that mountain. The main body of the Sligachan glacier, however, spread out over the moorland tract, following especially the Drynoch valley westward towards Loch Harport and the Varrigill valley northward towards Portree. The midstream-line can be traced out by the preponderance of gabbro boulders (derived mainly from the left side of the Sligachan valley) on one side, and of granite (derived from the right side) on the other, in the drift deposits. By taking a census of 200 or 300 boulders at each selected spot, of which

Cuillin district.
(Mr. Harker.)

Cuillin
district.
(Mr. Harker.)

more than ninety were chosen, it was found possible to draw this line with precision. After following the middle of the valley it swings round westward at Sligachan, and runs for some miles close to the Dunvegan high road. This westward diversion of the ice-stream is in itself enough to suggest that the natural outlet sea-ward by Loch Sligachan was more or less obstructed by the ice-sheet from the Scottish mainland, which hugged the eastern coast of Skye. It even seems probable that at one stage a tongue of the Scottish ice was forced up Loch Sligachan, for near the head of the loch occur boulders of Torridon Sandstone and other rocks which must have been derived from the east. At a later stage this extraneous pressure was apparently relaxed, and a second set of striae along the shores of the loch indicates a freer outlet in that direction. To this stage are probably to be referred the large erratics scattered over the surface. When these are examined in the same way as the boulders in the hummocky drift, and a line is drawn to divide preponderant gabbro from preponderant granite erratics, it is found that this line does not turn westward at Sligachan like the other, but continues northward very near to the Portree road, thus indicating a relief of the pressure from the east.

The glacier flowing southward from the central divide was probably not less powerful than that flowing north. It evidently filled the Camasunary valley to a great depth. On the left side the slopes of Blaven are glaciated nearly up to the crest-line, while on the right Sgùrr an Eìdhne (1,390 feet) and Sgùrr na Strì (1,623 feet) are moulded and polished by ice to their summits. The evidence of the striated surfaces, which are so conspicuous all over this neighbourhood, is confirmed by the distribution of the boulders. Granite from Ruadh Stac and Marsco is found not only along the valley but on the western slopes of Blaven. The most westerly granite *in situ* is at Meall Dearg, on the right side of the mouth of Harta Corrie. A line drawn from here S.S.E. and S., following the direction of the striae, defines the western limit of erratics of granite. This line passes a little east of Loch a Choire Riabhaich and along the ridge of Sgùrr na Strì. The striae so clearly preserved on the gabbro indicate, however, a still further westward spread of this glacier, showing that it obliquely crossed the south-eastern part of Druim nan Ramh, at a height of over 1,300 feet, into Coruisk itself.

The Coruisk valley, receiving the whole of the interior drainage of the southern and major portion of the Cuillins, was occupied by a great glacier, which, at its highest stage, was only just held in on the west by the main summit ridge, while on its east side it marched with the Camasunary glacier just described. That the latter was able to a certain extent to encroach upon the territory of the Coruisk glacier is indeed the best evidence of its important magnitude. Nowhere perhaps in Britain is there a more striking display of ice-moulding and glacial striations than on the rocks of naked gabbro which surround Loch Coruisk and border the adjoining sea-loch Seavaig. Loch Coruisk itself is a

rock-basin with a maximum depth of 96 feet, going down therefore 70 feet below the sea-level. The striæ, which extend almost continuously over all the surrounding slopes, seem to indicate an accumulation of ice which found exit only with difficulty through the narrow outlet. The difficulty arising from the form of the ground would be augmented by the pressure on the one hand of the Camasunary glacier, and on the other of the smaller glaciers which from the corries south of Sgùrr Dubh converged more directly upon the head of Loch Scavaig. At several points about the outlet of the Scavaig River, however, a second set of striæ running S.S.W. seems to indicate that at a certain stage the Coruisk ice and the smaller glaciers from the west may have shrunk sufficiently to allow a branch of the Harta Corrie glacier to pour more freely down Coire Riabhach and across the foot of Loch Coruisk to the sea.

Cuillin
district.
(Mr. Harker.)

The accumulations of boulders, large and small, which occupy many of the higher corries are often scarcely to be separated from the screes; and indeed these latter, though still receiving additions from the steep mountain slopes, probably date back in part to Glacial times. The drift-deposits proper, which run up the valleys to altitudes of 1,000 or even 1,500 feet, and overspread a considerable part of the moors to the north and west, fall under two distinct types. There is first the hummocky drift or "kettle moraine," noticed in the last *Annual Summary*. This does not, as a rule, extend far up into the mountain tract, but is found occupying the lower and more level parts of the valleys, and spreading over considerable areas of the more open country. Boulders varying in size usually compose the bulk of the mass; they are mostly subangular, but rarely scratched. The second type of drift is sharply distinguished from the first by the smooth flowing outlines which it imparts to the hills, contrasting with the irregular surface, holding numerous tarns and swamps, which is characteristic of the "kettle moraine." This smooth-surfaced drift goes higher up the valleys than the hummocky kind, occurs as a fringe to it, and extends beyond it away from the mountains. It sometimes attains also a greater thickness, exceptionally as much as 100 feet. In the valleys of the basalt country, where it is most developed, it consists usually of a reddish sandy clay enclosing small boulders, and some larger ones, the latter often striated.

The distribution of the hummocky drift and the circumstances in which it occurs support the view that it represents the material—subglacial, englacial, and superglacial—thrown down by stranded portions of glaciers cut off from their supply behind and melting as they stood. The same supposition explains the absence of moraines of recession. The largest area of this "kettle moraine" extends from Harta Coire northward to near Garadubh on the Portree road, a distance of ten miles. It sends an arm westward up the valley of Allt Dearg Mòr and another over into the Drynoch valley, but these do not extend farther than a mile and a mile and a half respectively. Its extension thus connects it with a late stage in the sequence of events, when the general

Cuillin
district.
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movement of the Sligachan glacier was towards the north ; while an examination of the boulders, as remarked above, shows that the material was brought down during the maximum glaciation, when the flow trended more westward. This accords with the supposed mode of origin of the "kettle moraine," and confirms the view that there was no break between the two stages of glaciation which for convenience have been distinguished.

Again, there is an evident connection between the "kettle moraine" and the surface erratics, often of large size, which are scattered over the ground. These generally occur in large numbers on the hummocky surface, but are scarcely found beyond its limits. It is a common observation, too, when a hummock is exposed in section, that the larger boulders in it occur towards the top.

Ireland.

Wicklow
and Wexford.
(Mr. Nolan.)

In continuing his revision of the superficial formations in the counties of Wicklow and Wexford, MR. NOLAN has found that the western flanks of the granite range display much less local drift than is found on the eastern and northern sides. The hills, too, present some different features. There is a general absence among them of cliffs, of deep and narrow valleys, originating in abrupt semi-circular basins like those of Glenmacnass and the Moraine Glen, and corries with mountain tarns situated at the foot of lofty precipices.

The declivities on the western side are much gentler, and are covered with an almost unbroken mantle of moor and peat-bog. Nor does the local drift usually attain such heights as it does in the districts to the north and east. In the valley of the Liffey, south east from Kilbride, it seldom ascends higher than from 900 to 1,000 feet, rising to 1,100 in the upper part, called the Glen of Kippure, and its branches. This deposit is a sandy boulder-clay, almost altogether made up of granite blocks and detritus, with some of slate or schist. In the Glen of Kippure, however, a pebble of black chert, such as is common in the limestone gravel, was found at a height of 1,100 feet, but it must be remembered that this kind of drift occurs at a greater elevation on the Dublin mountains, a few miles to the north.

A considerable spread of local drift is again met with at Lackan, some four miles to the south of Kilbride. The physical features of that neighbourhood are peculiar. The village stands on the flanks of a hill that forms the northern boundary of a great amphitheatre of mountains, of which Mullagheleevaun—the second highest summit in Wicklow—is the culminating height. The line of elevations is continued by Moanbane, the Black Banks, and the hills south and west of Blackditches to Hollywood, from which a low ridge extends northwards to Baltiboy's. A considerable area of low flat ground is thus enclosed, which, viewed from the neighbouring heights, appears to be so level a plain as to have led some observers to consider it as marking the floor of an ancient lake, particularly as deposits

of brown and leaden-coloured calcareous and tenacious clay, with fragments of shells, are occasionally met with under the local drift. This latter generally makes flat or slightly undulating ground, the central portions being covered with peat-bog. The average height of the drift here is about 700 feet, but it rises to 1,000 feet at "The Lodge" in the small valley to E.S.E. of Lackan. Wicklow
and Wexford
(Mr. Nolan.)

Southwards of this district to the foot of the hills that stretch westward from Wicklow Gap, the drift has been noted by MR. NOLAN only in occasional patches, the ground being rocky or moory, and strewn with numerous granite blocks. At Lockstown, however, it forms a remarkable terrace of granite detritus 29 feet high and extending for nearly a mile north-westward along the valley of the King's River.

The comparatively low-lying and cultivated country to the west of all this district is mainly covered with limestone drift of the same kind as that which prevails on the eastern side of the granite chain and generally over this part of Ireland.

Although rock-corries form no usual or conspicuous part of the scenery on the west of the granite range, mention must be made of a remarkable one at Mullaghcleevaun, where a mountain occupies a central position on the granitic highlands. The corrie is situated close to the summit, under precipices that face to the north-east. This deep and lonely hollow contains a small tarn called Cleevaun Lough, the waters of which are dammed up on the outer side by a mass of local blocks and débris, forming a small semicircular ridge.* Its position at a height of 2,244 feet under cliffs that tower 500 feet above is remarkable as testifying to the thickness of the ice-sheet, which must have covered even the highest of the Wicklow Mountains.

RECENT.

It is seldom that any novel features of interest or importance have to be reported regarding the more recent geological formations encountered by the Geological Survey. Last year progress was made in mapping the marine terraces in the south of England and along the western and north-eastern coast-line of Scotland. The superficial accumulations in the southern non-glaciated part of England were further mapped, and the peat-mosses in central England, the north-west of Scotland, and the east of Ireland were likewise traced on the large-scale maps.

Taking the south coast of Cornwall from Falmouth as a centre, MR. HILL has traced frequent marine terraces between Gerrans Bay and Helford River, of which perhaps the best example is the raised beach of Pendower in Gerrans Bay. A distinctive feature of these terraces is to be found in the compactness of the material of which some of them are composed. It is often so cemented together by iron-oxide as to simulate the appearance Cornwall.
(Mr. J. B.
Hill.)

* This little moraine has been already noticed by Rev. M. H. Close, *Journal Roy. Geol. Society, Ireland*, vol. v. part 1, p. 74.

Cornwall.
(Mr. J. B.
Hill.)

of some of the older geological formations, and in some districts it has served the purpose of building-stone. Even on the coast-line where the beaches are absent, a tiny fringe of gravel is often preserved. It may be observed running along some of the steeper cliffs, its preservation being obviously due to the durability of the cementing material, which has not only held the particles together, but has firmly bound the gravel to the rock on which it rests. The upheaval which has left these terraces in their present position has often materially changed the geographical features; for instance, the present peninsula of St. Anthony, above two miles in length, was before the uprise an island, as is demonstrated by the deposits of sand charged with marine shells on the neck of the peninsula.

These raised beaches are often overlain by the material which has long been known in Cornwall and to geologists generally as "head." This deposit is sometimes stratified, and may contain beds of fairly rounded gravel; more often, however, the tendency to stratification is but slight, and the deposit presents an irregular accumulation of stones, mostly angular, occasionally sub-angular. Such an accumulation is made up of material similar to the ordinary sub-soil of the district. If this sub-soil were transported from higher to lower levels it would probably form a deposit similar to the so-called "head," which often merges so gradually into the sub-soil as not to be separable from it.

Dorset.
(Mr.
Hinxman.)

Much of the ground where the Chalk rises to the surface is covered with a deposit which has long been known under the name of "clay-with-flints." In recently revising the maps of Dorset, Mr. HINXMAN has found that the greater portion of the high chalk-plateau which extends on either side of the Frome valley is covered with a deposit of orange or red clay, very stiff in the lower portion, but passing into a brownish loam near the surface. This deposit rests irregularly on the surface of the chalk, and varies from a few inches to 6 or 8 feet in thickness, with an average depth of about $2\frac{1}{2}$ feet. It is always more or less filled with angular chalk-flints irregularly disposed, though here and there a parallel arrangement of them can be detected. The upper portion of the clay often becomes gravelly, from the admixture of rounded pebbles of flint, jasper, vein-quartz, and quartzite. These materials have no doubt been derived from the waste of the Bagshot Gravels. Small deposits of sand and gravel are also found in several places, occupying shallow pipes or basins in the clay. The clay-with-flints shows no evidence of glacial action, and must be regarded as a *remunié* deposit derived from the waste of the Chalk and overlying Tertiary sands and gravels.

South Wales.
(Mr.
St. John.)

In the Bristol Channel, owing to the great vertical range of the tides, large tracts of low land are laid bare at low water, and these are more or less deeply coated with the silt and mud carried down into the estuary by the Severn and other streams. During the past year considerable tracts of such tidal alluvium have been mapped along the coast of South Wales. Some of these, such as Aberavan Marsh, lie behind the sand-dunes and must be of considerable antiquity. The tract in front of Aberavan has been

artificially drained; some sections at the east end were described in the *Annual Report* for 1896 (p. 84, Port Talbot). The Neath is tidal as far up as Aberdulais and its alluvium consists of blue estuarine clay used for brickmaking. The river escapes to the sea at Briton Ferry, but there is an equally good outlet for it along the alluvial flat on the west side of the Pennant hill of Coed yr Iarll. As recorded by MR. CODRINGTON* the rock was reached at Neath at a depth of 52 feet below clay, peat, and gravel, and in the piers of the Rhondda and Swansea Bay Railway Bridge at depths of 28 to 55 feet below low-water mark, the material here being partly alluvial and partly of glacial origin.

South Wales.
(Mr. Strahan.)

From the mouth of the Neath to that of the Tawe the shore is bordered by the range of sand-dunes known as the Crymlyn Burrows, behind which is enclosed another marsh a quarter of a mile in width at Jersey Marine, and extending two miles inland in Crymlyn Bog. A borehole put down near high-water mark at a point south of Halfway House reached the rock at a depth of 58 feet, after passing through 40 feet of sand underlain by some clay and gravel.

The Crymlyn Burrows are growing seawards in their western part by the formation of new low dunes south of the high water mark. The Baglan Burrows are spreading south-westward in a similar manner, but the Aberavan Burrows have been newly breached by the wind here and there in a manner which suggests that they are perhaps retreating landward.

A well-marked river-terrace forms the ground on which the southern end of Bridgend is built. It extends, with only one break at Coity Brook, on the left bank of the Ogmore from opposite Angelstown to near Merthyr Mawr. Others occur higher up the stream. The Vale of Neath contains a series of "fans" of gravel, brought down from the deep drift-laden cwms on either side of the valley and spread out as deltas on the alluvial flat below. Almost every fan has been utilised as a building site. One of the largest is occupied by Resolven.

Reference has already been made to some of the higher raised beaches on the coast of Scotland which were formed during the later part of the Ice Age. The most conspicuous of these are the 100-feet and 50-feet beaches, both of which play an important part in the coast scenery of the country. Besides these, however, other terraces occur at lower levels and also form prominent features along many parts of the sea-board. Nowhere are they more strikingly displayed than in the basin of the Firth of Clyde. During last year MR. GUNN traced the 25-feet beach as a narrow terrace along the north-west and north coasts of the island of Arran, sometimes as a platform of sandy and gravelly sediment, elsewhere only a shelf cut out of the rocks and studded with old sea-stacks, as at Imachar. Here and there, as at the Seriodan, near the north end of the island, the terrace is obscured by landslips. Generally a marked rocky cliff rises at the back of the terrace, in which caves are frequent. Little evidence of the

Arran.
(Mr. Gunn.)

* *Quart. Journ. Geol. Soc.*, vol. liv. p. 254 (1898).

Arran.
(Mr. Gunn.) higher beaches is observable along this coast except near the mouths of some of the streams, as at Lochranza, Catacol, and at Iorsa-waterfoot. The 100-foot beach is very conspicuous at the last-named place. Several other marine terraces may also be observed intermediate between it and the 25-foot beach.

Argyllshire.
(Mr. Syme.) On the Argyllshire coast similar phenomena have been observed. Raised beaches have been admirably preserved in many of the fiords and glens. At Kilmelfort these terraces cover a considerable area, the 100-foot beach being well-marked among them. Some of the beaches contain abundant marine shells, as on Easdale island. Again, a large cave, with two exits, has been found on Eilean nan Caorach, an islet in the Sound of Lorne about ten miles to the south-west of Oban, where the floor is covered with a stalagmitic incrustation and numerous shells. For some years past attention has been directed to the caves in the line of old sea-cliffs at the inner margin of the terrace on which the lower part of Oban is built. A new recess or rock-shelter of this kind, which was opened last year near to the railway-station, was found to have on its floor an accumulation in which bones of birds and other animals, shells, ashes, and pieces of flint were found.

Ross-shire.
(Mr. Peach.) While mapping the Loch Luichart and Easter Ross district last year MR. PEACH had occasion to observe the action of some of the rivers in carrying down and spreading out their alluvia. The various rock-basins of that part of the country are being rapidly filled up by the amount of detritus annually poured into them. Among the streams the River Bran may be singled out as having played a double part. On the one hand, at the lower end of Loch Coulin it has cut down the barrier and lowered the level of that sheet of water so as to isolate from it Loch Achanalt, which, as shown by the alluvial terraces on the present barrier was obviously once connected with it. On the other hand, at the upper end of Loch Coulin the river has silted up the lake and has spread out the great alluvial plain which stretches for some miles to the west. A considerable alluvial plain surrounds the head of Loch Luichart, formed of sediment principally brought down by the Grudie Water. The main branch of the Bran, or Conon, as it is here called, issues from Loch Coulin filtered and almost free from sediment. At the head of Loch Garve a wide plain of alluvium has been formed by the Black Water which is fast filling up the lake. In a lower part of its course the same river, by cutting the gorge in which the falls of Rogie occur, has considerably lowered the level and diminished the area of Loch Garve. The successive shores of the lake while it was being drained and the ravine was being deepened are marked by beach-deposits, which reach down to the top of the gorge.

Wicklow.
(Mr. Nolan.) An important feature in the recent revision of the Geological Survey maps of the East of Ireland has been the mapping of the areas of peat which were not originally represented on the maps. The outlines of the extensive mantle of peat that covers so much of the Wicklow Mountains have now been completely traced by

MR. NOLAN. This irregular tract extends from Killakee Moun- Wicklow.
tain, in the vicinity of Dublin, to Lough Nahanagan near (Mr. Nolan.)
Glendalough, a distance of 14 miles, having an average width of
from 6 to 7 miles. Its general character was described in the last
Summary of Progress. Peat-bog again appears capping the
cliffs that rise steeply over Lough Nahanagan on the south, and
extend north-westwards, forming the southern boundary of the
upper part of the valley of the King's River. The peat is often
10 or 12 feet thick, but it has been much denuded and presents a
ragged surface. It covers the flat top of the mountain behind the
cliffs, and also extends westward by the head of the Valleys of
Glendalough and Glenmalur to the Table Mountain at an
average elevation of 2,200 feet.

The flat bogs are of no great extent; the chief of them has been
already referred to as occupying the centre of the plain south of
Lackan. This bog consists of two main portions having a
combined length of two and a quarter miles by an average width
of one mile. The turf is much used for fuel.

NEW RAILWAY-CUTTINGS.

The cuttings made for lines of railway often supply invaluable
evidence to the geological surveyor. But unless visited soon
after being opened they are apt to be earthed over, sown with
grass, or otherwise obscured, unless where they consist of rocks
of sufficient durability to retain a vertical face. Consequently, it
has been the practice of the Geological Survey to examine such
excavations during their progress or soon after their completion,
and to take advantage of them for future maps or for the
revision of already published sheets. It is desirable that a record
should be kept, for public use, of all such new artificial sections,
and it is proposed to publish notes of them from time to time in
the *Annual Summary of Progress* of the Geological Survey.

During last year a number of new lines of railway have been
in course of construction in different parts of the country. Their
cuttings have been examined by members of the staff of the
Survey and the following notes of the sections have been prepared
by them.

Great Western Railway.—This railway company is now engaged (Messrs.
in making a more direct route to Exeter, by Newbury and the Woodward
Vale of Pewsey. The cuttings along this new line from Stert and Bennett.)
near Devizes to Westbury in Wiltshire, have been examined by
MR. WOODWARD and MR. BENNETT.

To the east of the Clock Inn at Stert a cutting showed the
Gault-clay overlain by an irregular and not persistent deposit
of chalky clay or marl from 3 to 6 feet thick, rarely as much as
10 feet. This deposit was in places covered with stiff brown or
grey clay. Usually the base of this surface-accumulation was
formed of a rubble of chalk or of rounded chalk stones, occasional
bits of flint, fragments of Upper Greensand, and greywether. In
some places there was a marly deposit without any stones, while
in others the cutting showed simply a white-washed clay, the

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joint-surfaces and cracks in the clay being coated with carbonate of lime derived from adjacent or formerly overlying deposits of marl. Occasional land and freshwater mollusca were met with. Accumulations of this nature occur here and there all the way from Stert to East Coulston; at the last-named locality the marly deposits rest on the Kimeridge Clay. For the most part they may be looked upon simply as relics of the denudation of the Chalk, Upper Greensand, and Gault.* The railway-cuttings showed that they occur as patches or pockets in old hollows, and the fact that much of the material has been decalcified renders it impossible to map such a soil with any approach to accuracy. The character of the land has, however, been greatly modified between Stert and Patney, and between Etchilhampton and Wedhampton, where this irregular clayey soil overlies the Upper Greensand.

In the cutting south and south-east of the Clock Inn at Stert, the stiff Gault-clay was to be seen passing upwards into somewhat sandy and dark greenish clay—the passage-beds into the Upper Greensand. Between Marsh Farm and Ruddlebats Hanging the cutting showed stiff Gault-clay. Further on to the west of Sparrow Cottage and for some distance the railway traverses slipped masses of Gault and Upper Greensand, and the scarp above shows a great slipped mass of Greensand. A little tract of Upper Greensand has been cut through at Fiddington Farm.

Further south the railway crosses the Gault north of Littleton Pannel and Great Cheverell. North-east of Home Farm a cutting shows the Gault-clay with ferruginous base, resting on the Portland Sands. Eastward the Gault is covered here and there with the irregular chalky Drift and débris of Upper Greensand, to which reference has been already made. Westward the Portland Sands, comprising green, yellow, and buff sands, have been opened up to a depth of 15 or 20 feet. No junction with the Kimeridge Clay was laid open. The clay has been exposed in the shallow cuttings north of East Coulston.

To the south-east of Lower Baynton Farm the Kimeridge Clay is covered with a patch of stiff chalky clay or marl, while by the stream north of East Coulston there is a local deposit of fine chalk gravel, with occasional fragments of greywether. In a subsequent examination MR. BENNETT observed that near Bratton a long cutting has been excavated in the Gault, surmounted in places by 8 or 10 feet of chalk-rubble and flint-gravel; and that this superficial chalky drift occurred on the low grounds opposite to the valleys at Tinhead and Bratton, whence it had evidently been derived.

South Wales Direct Railway.—The cuttings on this new line have been examined by MR. H. B. WOODWARD. The Railway diverges from the old main-line of the Great Western Railway a

* It is quite possible that some of the chalk-rubble is a relic of former agricultural operations. In old times it was not unusual to put 160 cart-loads of chalk on an acre, on both sandy and clayey lands. Davis, *Agriculture of Wilts*, 1794, pp. 63-65.

quarter of a mile west of Wootton Bassett, and extends for a distance of about 28 miles to Patchway, south-east of the Severn Tunnel. In a deep cutting which traverses Hunt Mill Lane near Wootton Bassett rubbly coral-limestones and clays of the Upper Corallian dip southwards at a considerable angle and are overlain by dark blue Kimeridge Clay. No evidence of the fault (shown on the Geological Survey map) was here observed, but the cutting was far from clear owing to débris covering the slopes. (Mr. Woodward.)

On the western side of Hunt Mill Lane there is a deep cutting in the Oxford Clay; and a similar cutting south-east of Whitehill Farm shows Oxford Clay with large specimens of *Gryphaea dilatata*. The next cutting on either side of the main road north of Dovey's Farm is also in Oxford Clay.

In the neighbourhood of Brinkworth several cuttings have been made in stiff grey clay and shales with cement-stones belonging to the Oxford Clay; covered here and there with two or three feet of clayey soil with flints, mostly subangular and angular.

This surface-Drift was well shown to the south-west of Brinkworth, where it occurs at a height of about 250 feet or more above sea-level, but not more than about 30 feet above the Brinkworth Brook. It is evidently a low-plateau gravelly drift, but it has no connection with the present stream. The valley-gravel which occurs further west on the borders of the River Avon is an oolitic gravel, made up largely of rolled and flat oolitic stones. The higher drift is almost entirely if not wholly an angular flint-drift.

MR. WOODWARD picked up five stones which appeared to him to resemble the Eoliths obtained from the plateau-gravel at Alderbury Hill near Salisbury. These were sent to DR. BLACKMORE, who writes, "Three are undoubted Eoliths, which I can match from Alderbury and other localities."

South of Little Somerford no cuttings were opened in the ground, but it is of a clayey nature. West of the road leading to Great Somerford four feet of sand were exposed in a cutting just commenced, and this sand no doubt belongs to the Kellaways Beds. Evidence of this group had been previously obtained at the adjacent Cemetery.*

On the west side of the River Avon and south-east of Angrove Cottages the rail passes over three or four feet of alluvial loam resting on oolitic gravel, with flat pebbles of limestone, etc. To the north and north-east of Bincombe Wood, south of Corston, a cutting about 20 feet deep displayed clay with septaria overlain by 10 to 20 feet of sandy and loamy beds, all belonging to the Kellaways division. From the clays MR. WOODWARD obtained *Ammonites Kœnigi*, *A. gowerianus*, *Cardium* and other lamellibranchs, and selenite. No doggers were seen in the sandy Kellaways Beds. The Cornbrash was exposed east of Kingway Barn. From the west of Kingway Barn

* Memoir on Jurassic Rocks of Britain, vol. v. p. 30.

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Woodward.)

to about half a mile west of Bradfield Farm, north of Hullavington, excellent sections of the rubbly Cornbrash were exposed to a depth of from five to ten feet. West of the Gauze Brook the Cornbrash was seen to overlie 12 feet of blue clays belonging to the Forest Marble, and these clays were exposed here and there on the slopes bordering Gauze Brook and in the valley a little further east.

To the south of Norton a cutting was made in the Forest Marble clays with some stone-beds, sands and doggers, the whole inclined gently towards the east.

Adjacent to the road from Townleaze Barn, 20 feet of shales with layers of sandy limestone exhibiting track-marks were exposed. Across the belt of Forest Marble the cuttings were few and of little interest. To the south-west of Furleaze Farm the soil is a red and brown brashy clay.

South of Cream Gorse thin sandy limestone and clay, and south-west of Low Barn grey clay and shelly oolitic limestone, were to be seen. On the west side of the road, between Alderton and "Elm and Ash," a shaft was sunk 30 feet mainly in stiff grey clay. Thence to Acton Turville and about half a mile west of the village there were occasional indications of clay, thin sandy limestone, and oolitic and shelly limestone belonging to the Forest Marble. Here and there a swallow hole has been noted on the Ordnance maps, where the surface-water is conducted through a thin capping of Forest Marble into the underlying Great Oolite.

A tunnel about $2\frac{1}{2}$ miles in length is in course of construction through the Cotteswold Hills between Acton Turville and Old Sodbury. This tunnel traverses the strata from the base of the Forest Marble to the upper portions of the Lower Lias. Seven shafts have been sunk along the line of the tunnel, and much water was encountered. The following details of the water found in these sinkings were communicated by MR. W. GREGORY:—

Shaft No. 1, north of Newhouse Farm, through base of Forest Marble into Great Oolite. Depth 111 feet. 3,000 gallons of water per hour.

Shaft No. 2, south-east of Lyegrove Farm, through Great Oolite into Fuller's Earth. Depth 148 feet. 350 gallons per hour.

Shaft No. 3, south of Lyegrove Farm, through Great Oolite and Fuller's Earth probably into Inferior Oolite. Depth 194 feet. 3,000 gallons per hour.

Shaft No. 4, south-west of Lyegrove Farm, through Fuller's Earth into Inferior Oolite. Depth 224 feet. 1,000 gallons per hour.

Shaft No. 5, east of Plough Farm, near the Cross Hands, through Fuller's Earth and Inferior Oolite. Depth 263 feet. 2,000 gallons per hour.

Shaft No. 6, west of Plough Farm, through Inferior Oolite and Cephalopoda-bed into Cotteswold Sands. Depth 281 feet. 10,000 gallons per hour.

Shaft No. 7, Old Sodbury. Through Middle Lias into Lower Lias clay. 200 gallons per hour.

The Cephalopoda-bed, portions of which were brought up from the shafts near the Cross Hands, was richly fossiliferous, and it presented its characteristic iron-shot character. Two

samples were examined by DR. W. POLLARD and found to contain in one instance 15·88 per cent. of metallic iron and 29·8 of silica, and in the other sample 17·96 of iron and 7·9 of silica.

Ammonites bifrons var. *hildensis*, and *A. striatulus* were obtained from the lower strata in Shaft No. 6.

On the slopes west of Shaft No. 6 the sandy loams of the Middle Lias were exposed. A brickyard north-west of the Village Farm showed stiff grey Lower Lias clays with some poorly preserved *Ammonites*, *Belemnites penicillatus*, and also a large specimen of *Inoceramus ventricosus* (undulated variety). The clays probably belong to the zone of *Ammonites Jamesoni*.

From this point onwards to Patchway the cuttings were visited a second time by MR. WOODWARD, and on this occasion in company with MR. STRAHAN. (Messrs. Woodward and Strahan.)

South of Colts Grove a cutting showed a slightly fractured anticline in the dark shales and clays, with a few thin bands of limestone and nodules belonging to the zone of *Ammonites semicostatus*. *Gryphæa arcuata* occurred here and some septaria, but with the exception of *A. semicostatus* few fossils were to be seen. The strata have but a very gentle dip eastwards.

South-east of Chipping Sodbury the cutting (18 feet deep in places, but about to be considerably deepened) showed beneath the clays with *A. semicostatus*, about ten feet of rubbly limestones belonging to the zone of *Ammonites Bucklandi*, and yielding *Ammonites Conybearei*, *Lima gigantea* (abundant), and *Gryphæa arcuata* (rare). The beds dip eastwards at 4° and rest on clays with occasional limestone-bands, the basement portion of which comprises several bands with *Ostrea liassica*, *Pleuromya*, etc., representing the *Ostrea*-beds of the zone of *Ammonites planorbis*.

The strata have been thrown into gentle undulations. The general section of the strata is as follows:—

Lower Lias.	Ostrea-beds.	Ft. in.
	Pale grey compact and shelly limestone, with small <i>Lima</i> , <i>Modiola</i> , and other bivalves - - - - -	1 6
	Brown and grey clay - - - - -	0 4
Rhætic Beds	Cotham stone - - - - -	0 2 to 0 5
	Grey highly calcareous marls and marly limestones seen to depth of - - - - -	12 0
	Black shales with <i>Avicula contorta</i> , <i>Cardium rhæticum</i> , and <i>Modiola</i> .	

Close to Lilliput Farm a thick mass of hard Carboniferous quartz-grit with occasional pebbles was found to project at the base of the railway with the black (Rhætic) shales banked against it and overspreading it. The grit dips westwards at an angle of about 40°. West of the road by Lilliput Farm the Carboniferous Limestone, with the same dip, has been deeply excavated. It includes bands of shale and thick beds of grit

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like that just mentioned, and which could not have been distinguished from Millstone Grit but for the fact that they are interbedded with a dark oolitic limestone and overlain by massive light-coloured limestone.*

These Carboniferous Rocks form the top of a crag which has been buried in Triassic sediments and subsequently revealed by denudation. The continuation of the cutting exhibits the banking of the marls against the steep westward face of the crag, and just suffices to show the top of the red marls terminating against the rising slope and overlapped by some friable buff-coloured dolomite associated with green marls, and evidently belonging to the Tea-green series. Large loose blocks of Carboniferous Limestone appeared to be incorporated with the marls, but the absence of any beach-deposit or of any water-worn material was particularly noticeable in these Triassic marginal deposits. A partial analysis of the buff-coloured dolomites by DR. POLLARD yields the following result:—

Earthy limestone, partially dolomitised, G.W.R., near Chipping
Sodbury.

Part insoluble in hot dilute HCl	-	-	19.5
CaO	-	-	27.7
MgO	-	-	11.4
FeO	-	-	1.6
Fe ₂ O ₃	-	-	2.1
Al ₂ O ₃	-	-	1.0
(CO ₂ calculated on CaO, MgO, and FeO)	-	-	35.7
P ₂ O ₅	-	-	trace
			<u>99.0</u>

Westwards a good section of Rhætic and Keuper Beds was to be seen, comprising 25 feet or more of the strata, as follows:—

White decomposed marl with <i>Modiola minima</i> , and with hard decomposed limestone in one or two bands.	
Grey clay	4 to 5 feet.
Pale grey and whitish marl, reddish-brown in places, having an irregular and almost nodular appear- ance when seen from a distance	9 feet.
Black shale with pyrites, <i>Cardium rhæticum</i>	} about 10 feet.
Thin sandstone, about $\frac{1}{2}$ inch	
Grey and tea-green marls—with calcareous gritty bands in places	about 8 feet.
Red and variegated marls (Keuper).	

The Tea-green marls were exposed in the valley S.S.E. of Raysfield Farm and again by the orchard and plantation N.N.W. of Chescombe Farm. The green marls fall to pieces readily in water, and after decantation leave a residue of minute crystals of calcite. The same fact has been noticed by MR. STRAHAN in green

* Similar beds noted as "firestone" were observed in the Carboniferous Limestone near Tytherington by the REV. H. H. WINWOOD. *Proc. Cotteswold Club*, 1889.

marls of this age in Glamorganshire, where, however, the crystals ranged up to half an inch in length and were so abundant as to form a heap after the removal of a lump of marl by rain. (Messrs. Woodward and Strahan.)

North-west of Wapley Common, both in the main-line and in a loop-line connecting with the Midland Railway, the red marls contained crystalline patches of celestine which occupied pockets of the red and variegated marls, but manifested no connection with the green tinges in the marls. The crystals were mostly small, none approaching in size those found near Wickwar.

South of Coalpit Heath the highest Coal-measures of the Coal-field are cut through; these comprise red, yellow, and purple shales with a few thin gritty bands dipping eastwards at about 25°. Overlying these is a stiff yellowish clay-soil three feet thick. Below the level of these strata in the ground to the west the railway passes through a tract where there have been many trials for coal, and some old coal-pits. Sandy shales were seen by the wood south of Blackberry Farm.

West of the Frome river at Huckford there is an old quarry in the Pennant Grit, and further west the rock has been exposed in a deep cutting which extends to the north of Prospect House, Winterbourne. The Pennant Grit here consists of thick and thin bedded sandstone, false-bedded and dipping eastward. It contains some irregular coaly seams together with an occasional large spherical dogger, and is much stained by iron-oxide, presumably from New Red rocks which formerly rested upon the strata. Towards the higher ground the beds are flaggy and much broken up, and the rubble is in places bent so as to exhibit "terminal curvature." The Pennant Grit, shown in the deep road-cutting, rests on mottled clays with veins of calcite. These clays bear some resemblance to Keuper Marls. Near the junction the Pennant Grit shows signs of fracture and slight displacement, due probably to land-slipping.

On the east side of the Bradley Brook three or four feet of red (alluvial) earth were seen over the Pennant Grit. Passing towards Stoke Gifford to the south-west of Mulgrove Farm a deep cutting has been excavated in red (Keuper) marls, with apparently impersistent bands of hard coarse-grained sandstone and blue marl with drusy cavities containing celestine.

These beds dip westwards, showing signs of slight displacement at one point, and are overlain by red and variegated marls and finally by 10 feet of grey marls at the base of the Rhætic series. These beds of grey marl contain in places impersistent layers and nodular masses of marly sandstone. The junction with the overlying Black Shales is sharp. Frequently there occurs a thin sandy layer at the junction. In some places the dark shale was seen to rest directly on the green marl, with a sharp plane of division, and in others there was evidence of slight disarrangement of the marl and of the incorporation of it with the black shale, but this was within the thickness of about one inch.

A good general section of the Rhætic Beds and basement-beds of the Lower Lias is continued westwards, interrupted by one or two faults which traverse the ground from N.E. to S.W. to the

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S.S.E. of Stoke Gifford. The series of strata there exposed may be tabulated as follows:—

Lower Lias. Ostrea-beds.		Ft. in.
Rhaetic Beds and Kemper Marls	Bands of pale compact limestone, showing false-bedding and clay with impersistent bands and nodules of Cotham Stone- - - - -	3 0
	Rusty band - - - - -	0 3 to 0 4
	Shaly marls with thin impersistent rusty bands -	1 2
	Pale shaly marl passing into thin-bedded White Lias here and there - - - - -	3 6
	Black shales—rusty where exposed - - - - -	1 6
	Dark grey earthy limestone - - - - -	0 1 to 0 3
	Grey and brown rusty clays and shales, with a few lenticular nodules of hard limestone - - - - -	10 0
	Thin sandy layer $\frac{1}{2}$ in. seen in places.	
	Tea-green, grey, and yellow rusty marls - - - - -	10 0
	Red and variegated marls.	

The Black shales at the surface become a stiff brown clay. The ground in places was found to be cracked down to the junction with the Tea-green and grey marls, a depth of about ten feet. At the western end of the cutting traces were observed of the Lower Lias limestones with *Unicardium carlioides*, &c.

West of the road and S.W. of St. Michael's Church, Stoke Gifford, the excavation for a new road bordering the railway showed the following section:—

		Ft. in.
Rhaetic	Clay soil with bits of White Lias - - - - -	1 0
	Marl and thin white limestone - - - - -	2 0
	Grey clay and stone with Cotham Marble - - - - -	1 0
	Brown and grey clay and rusty bands - - - - -	1 0
	Dark grey clay - - - - -	1 6
	Grey marly beds.	

The upper layers here were somewhat displaced by soil-movements on the sloping ground. In some examples of the Cotham or Landscape Marble the weathered surfaces showed the arborescent markings in relief.*

(Mr. Reid) *Railway from North Walsham to Mundesley, Norfolk.*—This new line was examined by MR. CLEMENT REID last spring. It is carried at so high a level that the shallow cuttings only expose sandy gravels, forming the upper part of the Glacial Deposits. These gravels, as a comparison of the cliffs with the inland sections in the Cromer railway had led us to expect, are little disturbed or contorted; in fact the only marked contortions were seen in the cutting between North Walsham and the Canal.

* See H. B. Woodward, *Geol. Mag.* 1899, p. 78.

II.—PETROGRAPHICAL WORK.

Much of the petrographical investigation carried on during the past year by the Geological Survey has been embodied in the foregoing account of the field-work of the staff. Some statistics may here be given, and thereafter a reference to some of the other results of the microscopical and chemical examinations may be added.

The number of specimens of rocks of which thin slides were prepared and microscopically examined and reported on by MR. TEALL was 369. They were collected partly in Devon and Somerset, but chiefly in the Highlands of Scotland. Thin slices of English and Scottish rocks to the number of 642 have been prepared during the year and added to the collection at Jermyn Street. The number of rock-specimens gathered by the collectors in Scotland amounted to 849 in illustration of the geology of the counties of Argyll, Inverness, Ross and Cromarty, Lanark, Ayr, Peebles and Midlothian. Of these no fewer than 666 were procured in Skye for the purpose of furnishing materials for the detailed study of the petrography of that interesting and complicated island. In the Irish branch of the Survey 162 thin slides of Irish rocks were prepared last year, and reports upon these have been furnished by MR. SEYMOUR.

The total number of thin slices of English and Welsh rocks now in the collection of the Survey in Jermyn Street is 3193; of Scottish rocks 8293, or together 11,486. The number of Irish slides in the Dublin Office is 2181.

Among the more important petrographical results of the work of the Survey in 1898 special mention may be made of the remarkable aegerine-granulites discovered by MR. CUNNINGHAM-CRAIG near Derry Lodge, Braemar. These have been studied by MR. TEALL who finds them to be new to Scotland, and so far as he is aware they have hitherto been unknown in any areas of Archaean crystalline schists. Their mineralogical composition suggests affinities with igneous rocks of the nepheline-syenite group such as those occurring in Sutherland (borolanites) and in the Christiania district.

In the Explanation to Sheet 75 and in the *Annual Report* of the Geological Survey for 1896, attention was directed to the occurrence of cordierite-bearing rocks in the Eastern Highlands; and the apparent absence of corundum, a mineral which might naturally be expected to occur in these rocks, was commented upon. This mineral has now been found by MR. TEALL in similar rocks from the Western Highlands near the Ben Cruachan mass of granite (*ante* p. 87). It was not detected in the thin sections, but in the residue left after treating the rock with hydrofluoric acid. If the similar rocks from the Eastern Highlands be treated in the same way, it is highly probable that corundum will be found in them also.

(Mr. Teall.) Corundum is known to be formed in two ways;—(1) as a product of the crystallization of igneous magmas, and (2) as a metamorphic mineral in contact-rocks. Illustrations of both these modes of formation are now known to occur in Great Britain. The case described by PROF. BUSZ of the occurrence of minute crystals of corundum in a felsite from South Brent is an example of the first, and the rock from the neighbourhood of Ben Cruachan, discovered by MR. KYNASTON, is an example of the second.

In addition to the ordinary routine work of the petrographical department, a series of microscopic slides of rocks from British Guiana, sent over by PROF. J. B. HARRISON, Government Analyst, has been examined and reported upon by MR. TEALL. The results have been published by the Government of the Colony in a Report on the Geology of the North-west District. In a letter recently received from PROF. HARRISON, it is announced that certain conclusions, suggested by an examination of the microscopic slides, as to the field-relations of some of the rocks, have since been confirmed.

In the last *Annual Summary* reference was made to the work done on specimens sent home by the JACKSON-HARMSWORTH polar expedition. A further series of rocks and fossils brought home by the expedition has been examined, and the results have been published by the Geological Society of London in a joint paper by MR. E. T. NEWTON and MR. TEALL.

Many enquiries relating to practical and scientific matters have been addressed to the petrographical department during the year and, in all cases, such information as was possible has been freely given.

In order to increase the value, for purposes of reference, of the large series of English and Scottish rocks now under MR. TEALL'S charge, a card catalogue has been prepared by MR. RHODES.

Much assistance has been obtained during the past year from chemical analysis in the determination of rocks, and in obtaining information regarding certain problems which the field-observations could not explain. MR. GRANT WILSON in Edinburgh has completed the analyses of 17 rocks from the Highlands. Most of these analyses have been embodied in previous pages of this *Summary*.

The need of more continuous chemical aid has pressed for some years upon the attention of the DIRECTOR GENERAL, and means were adopted by him last year to remedy this deficiency in the staff. Advantage was taken of a vacancy in the establishment to secure the services of an accomplished chemist, DR. POLLARD, who since his appointment has been uninterruptedly employed in the laboratory at Jermyn Street. The most interesting and important of his investigations has consisted in the detailed analyses of a series of Cambrian dolomites from Durness in Sutherland and the Isle of Skye. Other examinations which may be alluded to were that of a white clay from a boring at Leslie in Fifeshire, a nodule in Limestone from Glenelg, and a

specimen from a boring at Brabourne. An account of these investigations is given below. Several other analyses (for the most part partial) have been made, as well as the qualitative examination of several rocks and minerals for petrographical purposes, or the identification of minerals for museum specimens.

Cambrian Dolomites from Durness and Skye.—Some questions (Dr. Pollard.) of great interest having arisen both in the field-work and in the preparation of the descriptive memoir on the North-west Highlands, with regard to the dolomitization of the Cambrian limestones of that region, it was determined to subject some of the rocks to careful chemical analysis by DR. POLLARD.

The specific gravity of a series of specimens from Durness sent up for examination was first determined. As is seen from the following list the majority range between 2·80 and 2·86. That of Calcite is 2·72 and Dolomite 2·85–2·95 (Rosenbusch-Iddings).

List of specimens sliced and analysed :—		Sp. gr.
No. 8129. Quarry, 150 yards E. of Sango Bay, Durness	-	2·84
8130. Eilean Hoan, 2½ miles E. of Durness	- - -	2·85
8131. Eilean Dubh Group, Eilean Hoan	- - -	2·82
8132. Dolomitic Limestone in Fucoid shales, near Grindaidh, Kyle of Durness	- - -	2·81
8133. Big Croisiphuill (coarse, crystalline part)	- - -	2·78
(compact part, <i>see</i> analysis)	-	2·67
8283. Eilean Dubh Group, A'Ghoil Sgein, near Eilean Hoan	- - - - -	2·85

The following were neither sliced nor analysed :—

Eilean Dubh, Durness	- - - - -	2·85
Eilean Dubh Group, Sailmhor	- - - - -	2·83
Base of Mottled Group, Sailmhor	- - - - -	2·85
Eilean Dubh	- - - - -	2·86[Max.]
Mottled Limestone, Eilean Hoan	- - - - -	2·84
Dolomitic Limestone, Eilean Hoan, 2½ miles E. of Durness	- - - - -	2·83
Middle of Mottled Group, E. of Sailmhor	- - - - -	2·85
Flaggy beds, middle of Eilean Dubh Group, nr. Sailmhor	- - - - -	2·82
Dolomite above chert, base of Sangomhor Group	- - - - -	2·81
Near top of Mottled Group, Sailmhor	- - - - -	2·84
Limestone Skerry, Balnacuile Bay	- - - - -	2·82
Overlying Chert-bed, Sangomhor	- - - - -	2·84
Thin "band of" Dolomite" in Big "Croisiphuill, E. side of Lake Borrolaidh	- - - - -	2·84
About middle of Mottled Group, Sailmhor	- - - - -	2·84
Roadside, 250 yards E. of Sangomhor	- - - - -	2·83
Top of Eilean Dubh, Sailmhor	- - - - -	2·86[Max.]
Limestone Skerry, Bailnacuile Bay	- - - - -	2·85
" " " "	- - - - -	2·80
" " " "	- - - - -	2·85
" " " "	- - - - -	2·84
" " " "	- - - - -	2·73[Min.]
" " " "	- - - - -	2·82
" " " "	- - - - -	2·84
Salterella-Limestone, Gruidaidh group	- - - - -	2·85

From the specific gravity determinations it seems most probable that the specimens (with one or two exceptions)

(Dr. Pollard.) are Dolomites. The analysis of these Dolomites gave the following results:—

No. - - -	8129	8130	8131	8132	8283	8063	8064
Sp. gr. - -	2·84	2·85	2·82	2·81	2·85	2·85	2·86
Part insol. in dilute Hydrochloric acid -	1·83	2·42	15·81	28·96	2·01	2·26	1·72
SiO ₂ - - -	·16	·11	·29	·49	trace	·50	
FeO - - -		·34	·32	1·52	·35		
Fe ₂ O ₃ - - -	·21	·28	·36	·29	·10	·45	·34
Al ₂ O ₃ - - -				·50			
P ₂ O ₅ - - -	(trace?)	trace	·05	·62	trace		
MnO - - -	·17	·24	·19	·33	trace	·22	·19
CaO - - -	29·65	30·05	25·40	21·73	30·09	30·50	30·53
MgO - - -	21·53	20·25	18·24	13·61	20·83	21·19	20·81
CO ₂ - - -	46·62	46·15	39·65	31·45	46·59	44·54	46·25
Water - - -	—	—	—	·79	·28	—	—
TOTAL - -	100·17	99·84	100·31	100·29	100·25	99·66	99·84

Nos. 8063 and 8064 are specimens from Strath, Skye, sent up for analysis by MR. HARKER. The amount of insoluble residue in No. 8132 varies considerably in different parts of the specimen. The sample for analysis was prepared from chips from different parts of the hand-specimen.

Ratio of Lime to Magnesia and Carbon dioxide in the above specimens:—

	CaO	:	MgO	:	CO ₂
8129 - - -	1·0	-	1·02	-	2
8130 - - -	1·06	-	1	-	2·07
8131 - - -	1	-	1	-	1·99
8132 - - -	1·14	-	1	-	2·10
8283 - - -	1·03	-	1	-	2·03
8063 - - -	1·03	-	1	-	1·91
8064 - - -	1·05	-	1	-	2·02

The mottled Dolomite (No. 8129) contains small black inclusions, which occur most frequently in the dark patches. (This is clearly seen in the thin slice.) The part insoluble in dilute hydrochloric acid is blackish, owing to these minute specks. These were shown to be carbon, and an approximate determination (loss on ignition of residue after drying at 150°) gave ·06%. (The true amount may be even less owing to the possibility of part of the loss being due to water.)

Microscopic Examination of Slices 8129—8132 and 8283.

[8129] Crystals of carbonate, mostly with irregular outlines from .1 to 3mm. diameter. Occasional small veins of Limonite. The mottling seems to be due to very minute black grains included in many of the crystals. The crystals which outline the dark patches in the rock appear to contain more of these black inclusions.

[8130] Crystals of carbonate, mostly with irregular outlines, from .08 to .2mm. diam. Occasional grains and veins of Limonite, some very minute black grains as inclusions, less frequent than in 8129.

[8131] Crystals of carbonate with irregular outlines, from .005 to .003mm. diam., and occasional quartz grains of about the same size. Small patches and veins of Limonite.

[8132] Impure carbonate rock with Limonite, rounded grains of quartz and a pleochroic mineral, possibly hornblende. The carbonate crystals vary considerably in diameter (from .05 to .6mm.). The rock is obviously of organic origin. It contains numerous fragments of organisms, some, referred by Mr. E. T. NEWTON to the sponge-like forms *Archaeocyathus*, *Calathium*, &c., and others are pieces of Molluscan shells.

[8283] Crystals of carbonate with more or less irregular outlines. Occasional veins of Limonite, small carbonate crystals, and short veins of microcrystalline quartz. On the slice there is one patch of carbonate crystals, larger than the main mass, with V-shaped markings of Limonite, probably formed by the decomposition of siderite crystals.

[8133] The hand specimen of "Big Croisiphuill" consists of bands of crystalline carbonate, and a compact mass of carbonate and cryptocrystalline silica.

The slice shows bands of crystalline carbonate (crystals from .1 to .2mm. (diam.) with some Limonite, and cryptocrystalline silica containing carbonate crystals from .1 to .2mm. diam. There are minute black grains (carbon ?) in the carbonate bands.

The compact part was separated as cleanly as possible from the crystalline part, and each analysed. The results are :—

[8133]				Crystalline Part				Compact Part
Sp.Gr.	-	-	-	2.78	-	2.67		
Part insol. in dil. HCl				1.73	-	56.01		
SiO ₂	-	-	-	0.13	-	0.22		
FeO	-	-	-	0.16	-	} 0.27		
Fe ₂ O ₃	}	-	-	0.13	-			
Al ₂ O ₃								
MnO	-	-	-	0.25	-	trace		
CaO	-	-	-	32.54	-	22.43		
MgO	-	-	-	19.06	-	1.40		
CO ₂	-	-	-	45.82	-	19.24		
Water	-	-	-		-	0.31		
Total				99.82		99.88		

Ratio of CaO : MgO : CO₂ in crystalline part = 1.16 : 1 : 2.09. The residue of the compact part consists of 99.2 per cent. Silica.

A partial analysis was made of the specimen from the "Limestone Skerry from Bailnacuille Bay," sp. gr. 2.73. (Next lowest sp. gr. in the series is 2.80). This is seen to be a partially dolomitized rock, with a considerable amount of residue :—

Residue	...	...	...	19.9
Fe ₂ O ₃ Al ₂ O ₃	...	...	...	1.6
MgO	...	...	...	4.4
CaO	...	...	...	38.0

Attention should be drawn to a number of analyses of Sutherland limestones by DR. ANDERSON,* who analysed specimens from the following localities:—Knockdon, Elfine, Duirness, Eribol, Achmore, Stronchrubie, Kirktown, and Ledbeg. All these are practically true Dolomites, excepting Duirness, and the “white crystalline” from Ledbeg. Several other analyses are given by PROFESSOR HEDDLE (*Min. Mag.* iv. 239), who also quotes DR. ANDERSON’S analyses.

As it seemed just possible (though improbable) that these rocks might be a mixture of calcite and magnesite, or of calcite, magnesite, and dolomite, the ratio of Ca to Mg dissolved by water saturated with carbonic acid was determined. The specimens on which this was tried were 8129 and 8064. In both cases the ratio was practically 1 : 1. Had they been mixtures far more CaO than MgO would have been dissolved.

Similar results were obtained (with 8064) by the action of 1 per cent. HCl on the rock powder for varying lengths of time (15 to 40 minutes) at ordinary temperatures.

From the results here presented it is seen that, with one or two exceptions, the specimens are Dolomites and not Limestones.

A remarkable group of limestones appears among the crystalline schists of Loch Duich and Glenelg, Inverness-shire. A nodule from the Glenelg Limestone, sent up by MR. CLOUGH, was sliced and examined by MR. TEALL, who suggested that the minerals should be separated and analysed by DR. POLLARD. The following is a short account of the results of the microscopical and chemical examination of this nodule:—

[7923] Nodule in Limestone $\frac{3}{4}$ miles + 40 yards E. of Sgiath Bheinn, Glenelg. This nodule consists mainly of a mineral of the Olivine group, mostly quite fresh, and of an isotropic mineral of high refractive index embedded in an aggregate of grains of the former.

The minerals were separated by methylene iodide, and analysed. The Olivine mineral proved to be Försterite, and the isotropic mineral Spinel. In addition to the Spinel and Försterite there are also Calcite and Diopside, but not in great quantity.

In a boring for water at Leven Bank paper-mill, Leslie, Fife, under a sheet of intrusive dolerite about 50 feet thick, a “light fireclay” was pierced. This deposit, 27 feet and a half in thickness, rested upon soft white Lower Carboniferous sandstone, and possessed such a peculiarly greasy feel that a specimen of it was sent to the Geological Survey for examination. An analysis of it by DR. POLLARD gave the composition shown in the subjoined table:—

	SiO ₂	-	-	-	-	-	49·05
	Al ₂ O ₃	-	-	-	-	-	33·52
	CaO	-	-	-	-	-	·64
	MgO	-	-	-	-	-	·72
	K ₂ O	-	-	-	-	-	4·90
	Na ₂ O	-	-	-	-	-	·20
Water at 105°		-	-	-	-	-	5·45
Water above 105°		-	-	-	-	-	5·90
							100·38

* *Report of the Highland and Agricultural Society, 1851-53, p. 273.*

The peculiar greasiness to the touch at first suggested that this clay might be magnesian and might possibly be a decomposed product of some of the volcanic rocks of the Lower Carboniferous series. But the trifling proportion of magnesia in its composition shows that the peculiarity must be due to some other cause.

III.—PALÆONTOLOGICAL WORK.

The Palæontological Department at Jermyn Street continues not only to take charge of all the palæontological work required in the Museum of Practical Geology, but also examines and determines all fossils collected by the Geological Survey in England, Wales, and Ireland. The palæontological work of the Scottish branch is carried on at Edinburgh.

Among the various investigations in which the palæontologists at Jermyn Street, under the superintendence of MR. E. T. NEWTON, F.R.S., have been engaged during the past year, reference may be made to that connected with certain jaws, vertebrae, and other bones of a fish which were found by MR. CLEMENT REID some years ago in the Bembridge Marls of Hamstead, Isle of Wight, and which have been awaiting more material for their elucidation. This additional evidence has now been supplied by further specimens obtained by MR. G. W. COLENUTT in the Bembridge and Osborne Beds, near King's Quay, Ryde. All the specimens have been studied by MR. NEWTON himself, who refers them to the living ganoid genus *Amia* and proposes the name of *Amia anglica* for MR. REID's specimen and for one of those found by MR. COLENUTT in the Osborne Beds of King's Quay, which is likewise represented by several parts of the skeleton. Many of the isolated jaws in MR. COLENUTT's collection from these beds are believed to belong to the same species. A single slender maxilla also from the Osborne Beds and apparently belonging to the same genus, is referred to another species, to be called *A. Colenutti*. The close relationship of these forms to certain fish remains described by COPE, LEIDY, and MARSH from Tertiary rocks of North America, as well as the distribution of the closely allied forms both in North America and in Europe, are alluded to in a paper published by the Geological Society.

A block of sandstone obtained by MR. JOHN DAVID, of Porthcawl, Glamorganshire, from a quarry in Penarth Beds, at Stormy Down, near Bridgend, was found to contain the impression of a large reptilian jaw. The interest of the discovery was at once apparent to MR. R. H. TIDDEMAN, at whose request MR. DAVID very generously presented the specimen to the Museum of Practical Geology. The fossil, like so many of the well-known reptilian remains from the Elgin Sandstone, is merely a mould in the rock, the bone having disappeared. MR. NEWTON undertook the working out of the specimen, and having prepared casts in gutta percha, describes it as a left dentary bone of a megalo-sauroid reptile, with the dentition very perfectly represented

(Mr. E. T. Newton.)

(Mr. E. T.
Newton.)

The teeth are lodged in deep sockets, the larger ones being recurved, flattened from side to side, and serrated; the serrations on the posterior concave border extend from the point to very near the margin of the jaw, while those of the anterior convex border occupy only about two-thirds of the apical portion; in all the teeth this proportion is maintained. The presence of successional teeth in some of the alveoli, and of the points of others in some of the pits seen at the bases of the larger teeth, clearly show the mode of succession to be of the well-known type, where the germ of the new tooth appears on the inner side of the fully-developed tooth, and pressing upon the fang causes its absorption. The new tooth enlarging comes to occupy the interior of the fang of the old one, which by the continued absorption of its base falls out, or is easily broken off, when the new tooth is found occupying the middle of the alveolus, and subsequently comes to occupy the place of its predecessor. The genus *Zanclodon* (including *Teratosaurus*) is believed to be the most nearly allied fossil to this Bridgend specimen, and as it cannot be definitely referred to any known species it is named *Zanclodon cambrensis*. A full account of the fossil has appeared in the *Quarterly Journal of the Geological Society* (vol. liv., p. 646).

In a previous part of this *Summary* (p. 58) reference was made to the assistance derived by the field-surveyors in Ireland from the reports supplied to them by the palæontologists at Jermyn Street regarding the fossils collected from Silurian rocks. During the past year no fewer than ten different consignments of fossils have been sent from different Irish counties to the Museum of Practical Geology for determination. Although the specimens have for the most part been in a poor state of preservation, yet some good results have been obtained, which have much assisted the progress of the field-work. Early in the year a series of specimens from places in Wexford and Wicklow was examined and found to indicate Lower Silurian rocks, perhaps as low as the Arenig group. One set from near Arklow included specimens much resembling *Protovirgularia*, and hence seemed to indicate Upper Silurian rocks in that neighbourhood, but the identity of the organisms could not be established. A second series of specimens obtained from the same localities gave similar negative results.

Another series received from places near Arklow, Enniscorthy, and Courtown Harbour proved exceptionally interesting. From each of these places *Caryocaris Wrighti* was obtained together with *Didymograptus*, *Phyllograptus*, *Dicellograptus* and *Cenograptus*, leaving little doubt as to the Arenig age of the strata. A fourth series from Bray Head included examples of *Oldhamia*, but nothing else that might indicate the horizon of the rocks.

Two series of graptolites received from various places in Tipperary, were better preserved, and represented such forms as *Monograptus priodon*, *M. Flemingi*, &c. They thus showed the

rocks to be Upper Silurian, and probably of Tarannon or Wenlock (Mr. E. T. Newton.) age, some apparently high in the Wenlock series.

The examination of a selected series of graptolites from fifty-two localities south of Belfast confirmed the presence of strata of Llandeilo, Bala, Llandovery, Tarannon, and perhaps even of Wenlock age.

Late in the year a further collection was received from Tipperary which proved to consist almost wholly of *Monograptus riccartonensis*, thus indicating beds of Tarannon or Wenlock age. With these graptolites came a number of specimens from localities in Sheets 156 and 167, where the strata are much cleaved (*ante* p. 61.) These specimens are deserving of notice, although it is by no means certain that they are of organic origin. Many of them have the appearance of large graptolites, and one or two of the more distinct examples have so close a resemblance to a large-sized Monograptid, that if found alone they would almost certainly be regarded as such; and, indeed, it would be unwise to say positively that they are not graptolites much altered by pressure and cleavage. When, however, the whole series is examined, there is found to be a gradual change from these more clearly defined forms to others in which it is quite evident that the serrations are due to cross fractures and interruptions of the lines of cleavage. No one would be bold enough to assert that the latter specimens are graptolites, although it is possible they may be such, but almost destroyed by pressure and cleavage, while the more distinct forms first mentioned may be less altered specimens. On the other hand, it seems quite possible that even the most clearly defined forms may be altogether due to cleavage. One or two of these pseudo-graptolites are bent at an angle, and the portion which crosses the cleavage marks is serrated, while the part running parallel with the cleavage lines has no serrations. Some at least of these pseudo-graptolites are found on the cleavage planes, and not on the bedding, and the same may be said of certain fucoid-like markings found in the same slates.

In determining the graptolites MR. NEWTON has from time to time received valuable assistance from Professor Lapworth, who has always been ready to give the Survey the benefit of his long experience among these organisms.

Allusion was made in the *Summary of Progress* for 1897 to a further series of rocks and fossils brought back from Franz Josef Land by the Jackson-Harmsworth Polar Expedition, on the return of the party in the autumn of 1897. The examination of these specimens by MR. NEWTON and MR. TEALL has confirmed the conclusion arrived at from the study of the collection previously received. Some additional facts, however, were deemed worthy of being placed on record, and these have been embodied in a paper, "Additional Notes on the Rocks and Fossils from Franz Josef Land" (*Quart. Journ. Geol. Soc.*, vol. 54, 1898, p. 646). It was fully expected that a personal consultation with DR. KOERTLITZ, the geologist of the expedition, would necessitate some alterations of the altitudes given in the first paper (1897), and a

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few such alterations have been made, but fortunately they do not in any way alter the relative positions of the rocks. In view of the wide distribution of the common type of basalt, an analysis of it has been made and compared with analyses of two rocks from Iceland given by Bunsen, and the similarity is striking.

The widespread evidence of silicification in Franz Josef Land naturally suggests that siliceous springs may have existed there in times past, as they do at the present day in Iceland.

Further specimens of Radiolarian Chert have been obtained, but now as pebbles in a calcareous sandstone of Jurassic age, and are probably, as previously suggested by DR. G. J. HINDE, derived from rocks of Palæozoic age. Plant-beds similar to that already described on the north side of Cape Flora at a height of 700 feet above the sea, have been met with at other places around the Cape, and, although the plant-remains seem less abundant at the new localities, there is a similar assemblage of pine-needles, fern pinnules and Ginkgo leaves. It is tolerably evident, therefore, that this Upper Jurassic plant-bed extends over a large area at approximately the same level. At one place, it is true, a similar bed occurs at 900 feet, but this difference is probably due to the interpolation of the sheets of basalt. Another point of interest is the discovery of a fragment of *Ammonites Lamberti* in close relation with the base of the basalt and apparently about 50 feet above the horizon from which *Am. Tchefkini* was obtained, thus indicating the presence of Oxford Clay.

The bed at Windy Gully, east of Cape Flora, which yielded *Am. Ishmce* is now said to be about 400 feet above the sea (not 300 as before stated). Additional specimens of the last named species have been found, together with a Belemnite and parts of a large *Inoceramus*-like shell, the undulated surface of which reminds one of the Cretaceous *Inoceramus Cuvieri*.

From the locality 500 yards west of Elmwood additional and better preserved examples of the large *Avicula* have been found.

The carbonised and recent-looking vegetable remains from Cape Richthofen, which it was thought might perhaps be from Tertiary beds, have been submitted to DR. NATHORST, who thinks the absence of any fragment of a dicotyledon militates against their being of Tertiary age, and leads him to think that they may after all belong to the Jurassic rocks.

The large collection of British fossils now gathered together and displayed in the Museum of Practical Geology continues to be largely made use of by palæontologists, and specimens from it are frequently figured in illustration of their investigations. Thus in the course of the past year MR. A. BELL, in his paper "On the Pliocene Beds of St. Erth" (*Trans. R. Geol. Soc., Cornwall*, vol. 12, part iii. 1898), has figured *Columbella erythrostoma*, Bon., *Kellia corbuloides*, Phil., *Littorina gibbosa*, E. and B., and *Odostomia magna*, E. and B. MR. G. C. CRICK, in his memoir "On the Muscular Attachment of the Animal to its Shell in Some Fossil Cephalopoda" (*Trans. Linn. Soc.*, vol. 7, p. 4, 1898), has figured *Turritites tuberculatus*, Bosc., and *T. Mantelli*,

Sharpe, from the Lower Chalk, while Miss J. DONALD, in her (Mr. E. T. paper on Carboniferous Gasteropoda (*Quart. Journ. Geol. Soc.*, ^{Newton.} vol. 54, pl. v. fig. 5, 1898), has given a figure of *Rhabdospira compacta*, Donald, from the Yoredale Rocks of Wensleydale. MR. CLEMENT REID has figured *Limnocarpus* from the Tertiary Deposits of Hampshire. (*Proc. Linn. Soc.*, Botany, vol. xxxiii., p. 464).

Besides these a considerable number of the Jermyn Street specimens have been figured in the monographs of the Palæontographical Society for 1898, as shown in the subjoined list, which is here given in full, as it contains the names of what have now become type specimens.

Specimens figured by PROF. T. RUPERT JONES and DR. H. WOODWARD in their "Palæozoic Phyllopoda":—

Dithyrocaris testudinea, Scoul.
 „ *Colei*, Portl. Six specimens.
 „ *orbicularis*, Portl.

Specimens figured by the REV. G. F. WHIDBORNE, M.A., in his "Devonian Fauna of the South of England":—

Chonetes margaritacea, Whid.
Discina nitida, Ph.
Lepidesthes? devonians. Three specimens
Protocardaris acuaria, Whid. Two specimens.
Palæaster longimanus, Whid. Three specimens.
Protaster granifer, Whid. Two specimens.
Eugaster? perarmatus, Whid.
Protaster? scabrosus, Whid. Three specimens.
Ophiurella? gregaria, Whid.
Adelocrinus hystrix, Ph. Two specimens.
Actinocrinus Porteri, Whid. Four specimens.
Rhodocrinus?
Actinocrinus? Batheri, Whid. Two specimens.
Taxocrinus macrodactylus, Ph. Three specimens.
Scaphiocrinus? inordinatus?, Whid.
 „ *? sp.*
Poteriocrinus. Two specimens.
Scaphiocrinus? plumifer, Whid.

Specimens figured by DR. WHEELTON HIND, B.Sc., F.G.S., in his "British Carboniferous Lamellibranchiata":—

Protoschizodus aciniformis, Portl. Two specimens.
 „ var. *depressus*, Portl. Two specimens.
Cardiomorpha corrugata, McCoy.

The Palæontological Department of the Geological Survey in Scotland. Scotland is carried on under the supervision of MR. B. N. PEACH, (Mr. B. N. with the assistance of the Fossil Collectors, MR. A. MACCONOCHIE ^{Peach.} and MR. D. TAIT. During the past year fossils to the number of 858 have been collected from the Cambrian rocks of Skye, the Upper Silurian rocks of Lanarkshire, Ayrshire, and the Pentland Hills, the Lower Old Red Sandstone and Carboniferous rocks of Lorne and Edinburgh.

It has been the custom of the Acting Palæontologist in Scotland, with the Director General's consent, to distribute certain groups of fossils among specialists for identification and for the publication of descriptions of new forms. Thus the Silurian, Old Red Sandstone, and Carboniferous fishes have been

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submitted to DR. TRAQUAIR, who has determined upwards of 800 specimens during the year, and who has furnished the separate notes given on pp. 65 and 72, regarding the forms collected during the past season. About 40 specimens of sponge-like bodies from the Down-tonian rocks have been submitted to DR. G. J. HINDE. DR. MALCOLM LAURIE has examined the collection of eurypterids from the Upper Silurian and Lower Old Red Sandstone rocks collected during the last few years, and has been supplied with specimens of some new forms for description. MR. R. KIDSTON has named 13 specimens of fossil plants from the Lower Old Red Sandstone, 209 specimens from the Carboniferous rocks of Arran, a few Lower Old Red Sandstone Plants from Lorne, and a small but interesting collection of 19 specimens of fossil plants from the red sandstones occurring near the Bridge of Awe, referred to on p. 129. MR. J. W. KIRKBY has reported upon a small collection of specimens of *Ostracoda* from the Lower Carboniferous rocks underlying Edinburgh (p. 132). A collection of about 200 Cambrian fossils from Skye and about 20 specimens of graptolites from the Wenlock rocks of the Pentland Hills have been determined by MR. PEACH. Thus in all upwards of 1,200 fossils have been determined during the year. Some of the more important results of the examinations have been embodied in previous pages of this volume.

During the year there have been figured from the Scottish Survey Collection in the Museum of Science and Art, Edinburgh, for the monographs of the Palæontographical Society for 1898 the following specimens:—

By T. RUPERT JONES and DR. H. WOODWARD in their "Palæozoic Phyllopoda":—

- Calyplocaris striata*, Woodward. One specimen.
- Dithyrocaris Colei*, Portlock. One specimen.
- " *glabra*, Woodw. and Eth. One specimen.
- " *granulata*, Woodw. and Eth. Two specimens.
- " *lateralis*, M'Coy. Two specimens.
- " *ovalis*, Woodw. and Eth. One specimen.
- " *Scouleri*, M'Coy. One specimen.
- " *tricornis*, Scouler. One specimen.

By DR. WHEELTON HIND in his "British Carboniferous Lamellibranchiata":—

- Protoschizodus æquilateralis*, M'Coy. Two specimens.
- " *nuculoides*, M'Coy. Two specimens.
- " *obliquus*, M'Coy. Two specimens.

IV.—PRACTICAL APPLICATIONS OF THE WORK OF THE GEOLOGICAL SURVEY.

From the beginning of their existence the Geological Survey and the Museum of Practical Geology have had regard to the industrial and economic applications of Geological Science. Every year the practical usefulness of the data collected by these institutions is becoming more widely recognised, so that a

large part of the time of the resident officers in London, Edinburgh, and Dublin requires to be given to the supplying of information and guidance in matters which involve a knowledge of geology and of the geological structure of the British Isles. Nor are the questions confined to these islands; they frequently relate to the colonies and to foreign countries. Hundreds of applications are made every year by the general public, while the various public departments are constantly requesting advice in similar directions.

During the past year enquiries have been frequent with regard to building-sites, especially in the neighbourhood of London, the publication of the Survey volume on "Soils and Subsoils" having called public attention to the importance of a careful consideration of this subject. A large proportion of the applications have had reference to questions of water-supply, and the maps of the Survey (on the scale of six inches to a mile) are found to be invaluable in such matters, as well as generally in sanitary engineering. These maps are for the most part unpublished, the large scale and the consequent cost of engraving having hitherto prevented their publication. But manuscript copies of them are deposited in each of the three offices of the Survey (London, Edinburgh, and Dublin), for consultation by the public, and they are largely made use of.

Among other subjects in which advice has been sought for, mention may be made of soils in relation to agricultural development; sites for market gardens; situations for cemeteries; routes for light railways; position, extent and quality of building-stones, limestones, road-metal, coal-seams, and coal-mining, metallic ores, peat, and many other stones, rocks, and minerals.

Among the Public Departments which have sought the assistance of the Survey, reference may be made to the Local Government Board, and especially its medical and engineering branches; the Board of Agriculture, the Colonial Office, the War Office, the General Post Office, the Government Laboratory at Demerara, &c. Information has also been given to the Society of Antiquaries in respect to Roman tesserae obtained at Silchester.

V.—MAPS, SECTIONS, MEMOIRS, &c., PUBLISHED DURING 1898.

A.—OFFICIAL.

I.—MAPS.

1.—*England and Wales.*

New Series.—Thirteen sheets of the New Series of one-inch maps have been published during last year, viz. :—

Sheets 36, 45, 56, and 57 in one sheet (= No. 100 Old Series), Isle of Man, by G. W. LAMPLUGH.

Sheet 267, Newbury, by F. J. BENNETT.

Sheet 268, Reading, by J. H. BLAKE, with part by F. J. BENNETT.

Sheet 283, Andover, by F. J. BENNETT and C. E. HAWKINS.

Sheet 300, Alresford, by C. E. HAWKINS.

Sheet 328, Dorchester, by C. REID, A. STRAHAN and A. J. JUKES-BROWNE.

Sheet 350, Torquay, by W. A. E. USSHER.

Sheet 355, Kingsbridge, by W. A. E. USSHER.

Sheet 356, Start Point, by W. A. E. USSHER.

Of the above maps, that of the Isle of Man and of Reading are issued in two editions, Drift and Solid; the other maps are only issued with Drift.

Old Series.—Quarter-sheet 46 S.E., Drift Edition, has been published, the survey having been made by W. WHITAKER, A. C. G. CAMERON, and A. J. JUKES-BROWNE. Quarter-sheet 54 N.W., Revised Edition, Solid, has been published with revisions made by W. GIBSON, as notified in the *Summary of Progress* for 1897 (p. 67).

General Map on the Scale of Four Miles to an Inch.—The colour-printed edition of this map has now been completed, Maps Nos. 5 and 14, the two remaining Sheets, having been published during the year.

Six-inch Reference Maps.—102 MS. Coloured Copies of six-inch sheets and quarter-sheets have been made from the field-copies and deposited in the office for public reference. These are as follows:—

Bedfordshire.—33 S.W.

Berkshire.—28.

Brecknockshire.—32 S.E.; 33 S.E., S.W.; 34 S.W.; 38 N.E., S.E.; 39 N.E., N.W., S.E., S.W.; 40 N.W., S.W.; 44 N.E., N.W., S.E., S.W.; 45 N.E., N.W., S.E., S.W.; 46 N.W., S.W.; 49 N.E.; 50 N.E.

Buckinghamshire.—13, 14, 20, 23, 24, 28, 29, 33.

Cornwall.—37 N.E., S.E.; 38 N.W., S.W.; 45 N.W., S.W., N.E., S.E.; 46 N.W., S.W.; 54 N.W., N.E., S.E.; 55 N.W., S.W.

Devonshire.—23 S.E.; 24 S.E., S.W.; 34 N.E.; 35 N.W.; 107 N.E., N.W.; 111 N.W., S.E.; 117 N.E., N.W., S.E., S.W.; 119 N.W.

Glamorganshire.—25, 33, 39, 40, 50.

Hampshire.—48, 57, 63, 64, 65, 74, 75.

Isle of Man.—5.

Lancashire.—106 N.E., S.E., N.W., S.W.; 113 N.E., N.W. (Copies made from maps lent by Mr. G. H. MORTON, F.G.S.)

Leicestershire.—36 N.E., S.E.; 37 S.W., S.E.; 38 S.W.

Middlesex.—11 S.W.; 16 N.W.

Northamptonshire.—40 S.W.; 61 N.W., S.W.

Oxfordshire.—18.

Somersetshire.—9 N.E., S.W., S.E.; 10 N.W., S.W.

Worcestershire.—10 S.W.; 16 N.W.

Wiltshire.—70, 71.

Besides the maps above referred to as published during the past year, the following seven sheets of the one-inch map (New Series) are in the hands of the engravers:—

155, Atherstone and part of Charnwood Forest.

248, Pontypridd in the South Wales Coal-field.

282, Devizes and part of Salisbury Plain.

325, Exeter.

339, Newton Abbot and Teignmouth.

340, Otterton, near Budleigh Salterton.

349, Plymouth and Ivybridge.

Other sheets nearly ready for the engraver are:—

123, Stoke-on-Trent.
187, Huntingdon.
203, Bedford.
220, Leighton Buzzard.
231, Merthyr Tydfil.
261 and 262, Bridgend.
315, Southampton.
316, Havant.

2.—*Scotland.*

Two sheets of the one-inch map of Scotland have been published, viz.:—

19, Argyllshire.
85, Elginshire.

Also revised editions of the following four sheets:—

7, Ayrshire.
40, Fife and Kinross.
57, Forfarshire, &c.
67, Kincardineshire.

Two sheets of the one-inch map are in the hands of the engravers, namely:—

46, Tyndrum and Balquhidder.
55, Blair Athole.

Other maps are nearly ready for the engraver, namely:—

27, North part of Islay.
37, Inverary.
38, Lochs Lomond and Katrine.
86, Huntly.

3.—*Ireland.*

A revised edition of Sheet 29, Carrickfergus, has been published.

Revised editions of Sheets 37 and 38 have been prepared and will shortly be published.

Duplicate copies of the following sheets of the six-inch scale county maps have been prepared and deposited in the Dublin office for public reference:—

Co. Waterford.—Part of Sheet 3.
Wexford.—Sheets 29 and 49.

II.—MEMOIRS.

1.—*England and Wales.*

Six Memoirs have been published during the year, viz.:—

“Summary of Progress of the Geological Survey of the United Kingdom for 1897, with an Introduction regarding the History, Organisation, and Work of the Survey,” pp. vii., 176. Price 1s.

“The Geology of the Country around Bournemouth.” (Explanation of Sheet 329, New Series.) By CLEMENT REID, pp. iv., 12. Price 4d.

- "The Geology of the Country around Eastbourne." (Explanation of Sheet 331, New Series.) By C. REID, pp. iv., 15. Price 6d.
- "Supplement to the Geology of the Neighbourhood of Flint, Mold, and Ruthin." (Explanation of Quarter-sheet 79 S.E., Old Series.) By AUBREY STRAHAN, pp. 7. Price 2d.
- "The Geology of the Isle of Purbeck and Weymouth." (Explanation of Sheets 341, 342, and 343, New Series.) By A. STRAHAN, pp. xi., 278. Price 10s. 6d.
- "The Geology of the Borders of the Wash, including Boston and Hunstanton." (Explanation of Sheet 69, Old Series.) By W. WHITAKER and A. J. JUKES-BROWNE, pp. vi., 147. Price 3s.

Besides the Memoirs which have been published during the year, several others are far advanced or nearly ready:—

In the Press.

- "The Water Supply of Sussex from Underground Sources." By W. WHITAKER and C. REID. [Published 1899, Price 3s.]
- "The Geology of the Country around Carlisle." (Explanation of Sheets 11, 16, and 17 New Series, 107 Old Series.) By T. V. HOLMES. [Published 1899. Price 1s. 3d.]
- "The Cretaceous Rocks of Britain," vol. i. The Gault and Upper Greensand of England. By A. J. JUKES-BROWNE.

In Preparation.

- "The Geology of the Isle of Man." By G. W. LAMPLUGH.
- "The Geology of Belford, Holy Island, and the Farne Islands, Northumberland." By W. GUNN.
- "The Geology of the Country around Kingsbridge and Salcombe." By W. A. E. USSHER.
- "The Geology of the Country around Reading." By J. H. BLAKE.
- "The Geology of the Country around Dorchester." By C. REID.
- "The Geology of the Country between Atherstone and Charnwood Forest." By C. FOX-STRANGWAYS, with Notes by W. W. WATTS.
- "The Geology of the Country around Newport, Mon." By A. STRAHAN.
- "Guide to the Geology of London." Sixth Edition. By W. WHITAKER.

2.—Scotland.

No memoir has been issued during the past year, but the first volume of the General Memoir on the Silurian Rocks of Britain which consists of a full detailed account of the Silurian formations of the Southern Uplands of Scotland, is passing through the press, and will be published immediately.

The important Memoir referred to in last *Summary of Progress*, as having been planned for the description of the complicated region of the north-west Highlands has made considerable progress during the past year. It is expected to be ready for the press by the end of the present year.

3.—Ireland.

A Memoir on the Soils and Subsoils of Ireland has been prepared in the Dublin Office by MR. KILROE, with the partial assistance of his colleagues, MESSRS. NOLAN, EGAN and MCHENRY. This work when published will, it is hoped, be of considerable service in the cause of Irish agriculture.

B.—NON-OFFICIAL.

The following is a list of the non-official publications of the members of the staff during the year 1898 :—

BARROW, G.—“On the Occurrence of Chloritoid in Kincardineshire.” *Quart. Jour. Geol. Soc.*, vol. liv., pp. 149-156.

BLAKE, J. H.—“Excursion to Reading.” *Proc. Geol. Assoc.*, vol. xv., pp. 304-308.

CANTRILL, T. C.—“The Contents of a Carn at Ystradfellte, co. Brecon.” *Archæologia Cambrensis*, 5th series, vol. xv., pp. 248-264, July, 1898; also *Journ. Anthropol. Inst.*, August and November, 1898, pp. 3, 4.

GEIKIE, SIR A.—“Types of Scenery and their Influence on Literature”: the Romanes Lecture for 1898. 8vo, London. Summary in *Nature*, vol. lviii., p. 179.

GEIKIE, SIR A.—“Antarctic Geology.” Remarks at Meeting of the Royal Society held on February 24, 1898, to consider the Scientific Advantages of an Antarctic Expedition. *Proc. Roy. Soc.*, vol. lxii., pp. 446-449; and *Nature*, vol. lviii., p. 426.

GEIKIE, SIR A.—“Science in Education.” Address to the Students at Mason University College, Birmingham, October 4, 1898. *Nature*, vol. lix., p. 108.

GOODCHILD, J. G.—“Obituary Notice of Dr. Heddle.” *Mineralogical Magazine*, 1898.

GUNN, W.—“Notes on the Geology of the Isle of Arran.” *Trans. of the Edinburgh Geological Society*, vol. vii., p. 268.

GUNN, W.—“Notes on the Correlation of the Lower Carboniferous Rocks of England and Scotland.” *Geol. Mag.*, Dec. IV., vol. v., p. 312.

HARKER, ALFRED.—“The Natural History of Igneous Rocks. II. Their Forms and Habits.” *Science Progress (N.S.)*, vol. ii., pp. 203-218.

HARKER, ALFRED.—“Norwegian Rhomb-porphyrries in the Holderness Boulder-Clays.” *Proc. Yorks. Geol. Pol. Soc.*, vol. xiii., pp. 279-280.

HARKER, ALFRED.—“Petrographical Research among Sedimentary Rocks.” *Trans. Hull Geol. Soc.*, vol. iv., pp. 17-20.

JUKES-BROWNE, A. J.—“On an Outlier of Cenomanian and Turonian [equivalent to Lower and Middle Chalk] near Honiton, with a Note on *Holaster altus*, Ag.” *Quart. Journ. Geol. Soc.*, vol. liv., pp. 239-250.

JUKES-BROWNE, A. J.—“The Delimitation of the Albian and Cenomanian in France.” *Nat. Science*, vol. xiii., pp. 193-201.

JUKES-BROWNE, A. J.—“Les Limites du Cénomanien.” Réponse à M. Gustave F. Dollfus. *La Feuille des Jeunes Naturalistes*, Ser. III., Aug., 1898.

JUKES-BROWNE, A. J. and J. MILNE.—“On the Cretaceous Fossils found at Moreseat, Aberdeenshire.” *Geol. Mag.*, Dec. IV., vol. v., pp. 21-32.

LAMPLUGH, G. W.—“Some Open Questions in East Yorkshire Geology.” *Trans. Hull Geol. Soc.*, vol. iv., pp. 24-36.

NEWTON, E. T.—“Palæolithic Man.” Presidential Address to the Geologists' Association. *Proc. Geol. Assoc.*, vol. xv., p. 246, 1898.

NEWTON, E. T. and J. J. H. TEALL.—“Additional Notes on Rocks and Fossils from Franz Josef Land.” *Quart. Journ. Geol. Soc.*, vol. liv., p. 646, 1898.

REID, C.—“The Eocene Deposits of Devon.” *Quart. Journ. Geol. Soc.*, vol. liv., 1898, pp. 234-238.

REID, C.—“On *Limnocarpus*, a new Genus of Fossil Plants from the Tertiary Deposits of Hampshire.” *Journ. Linn. Soc. Botany*, vol. xxxiii., pp. 464-466.

REID, C.—“Further Contributions to the Geological History of the British Flora.” *Annals of Botany*, vol. xii., pp. 244-250.

SHARMAN, G., and E. T. NEWTON.—“Notes on some Additional Fossils collected at Seymour Island, Graham's Land, by Dr. Donald and Capt. Larsen.” *Proc. Roy. Soc. Edinburgh*, vol. xxii., p. 58, 1898.

STRAHAN, A.—“On the Revision of South Wales and Monmouthshire by the Geological Survey.” (*Brit. Assoc.*, Bristol, 1898.) *Geol. Mag.*, Dec. IV., vol. v., pp. 488-493.

STRANGWAYS, C. FOX.—“Sections along the Lancashire, Derbyshire, and East Coast Railway, between Lincoln and Chesterfield.” *Quart. Journ. Geol. Soc.*, vol. liv., pp. 157-167.

TEALL, J. J. H.—“A Phosphatized Trachyte from Clipperton Atoll, Northern Pacific.” *Quart. Journ. Geol. Soc.*, vol. liv., pp. 230-232.

USSHER, W. A. E.—“The Geological Structure of Devon.” *Trans. Plymouth Inst.*

WEDD, C. B.—“On the Corallian Rocks of Upware (Cambs).” *Quart. Journ. Geol. Soc.*, vol. liv., pp. 601-619.

WOODWARD, H. B.—“On Arborescent Carboniferous Limestone from near Bristol.” (*Brit. Assoc., Bristol, 1898.*) *Geol. Mag.*, Dec. IV., vol. vi., pp. 77, 78 (1899).

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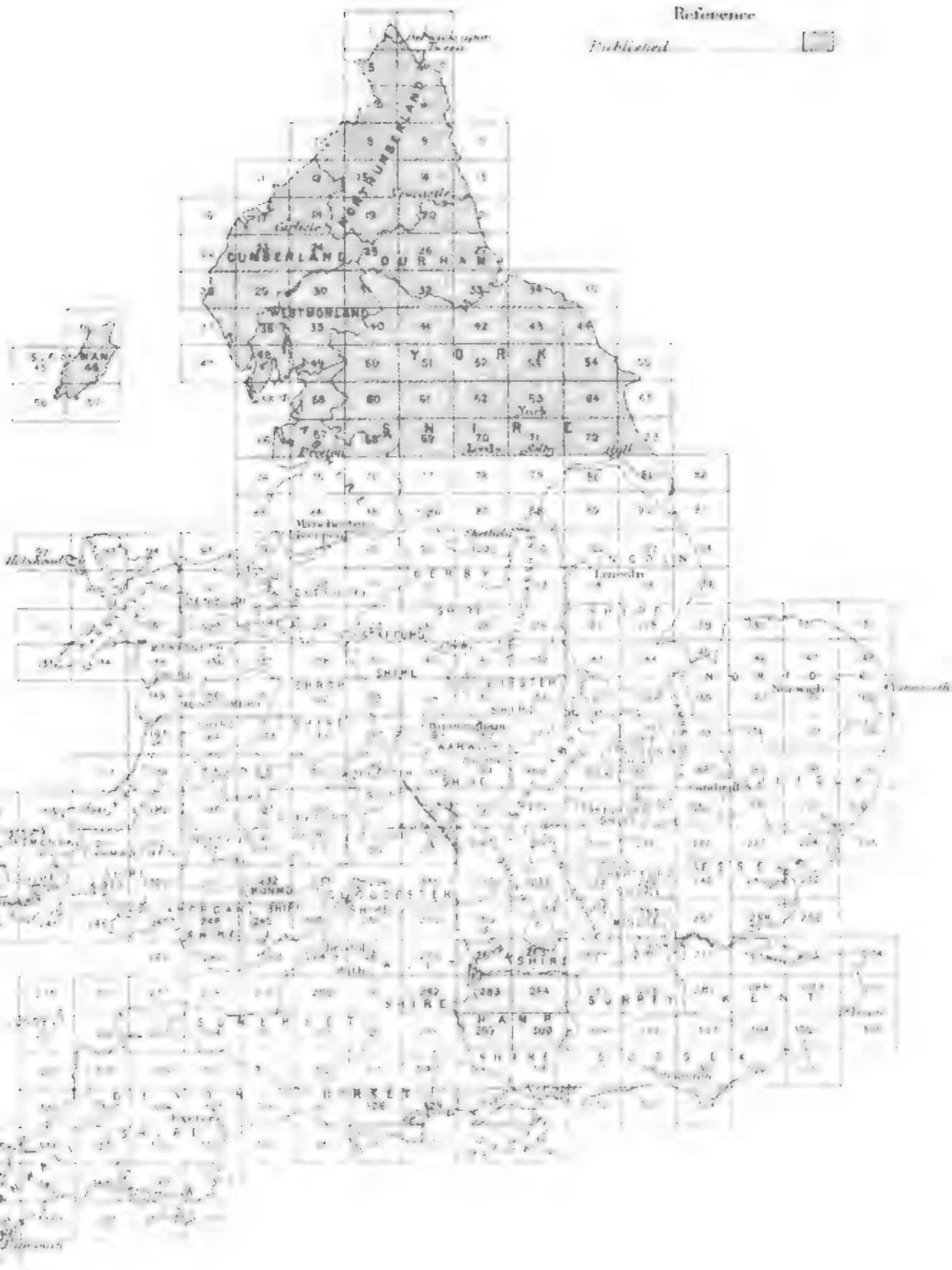
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Published on the Scale of One Inch to a Mile

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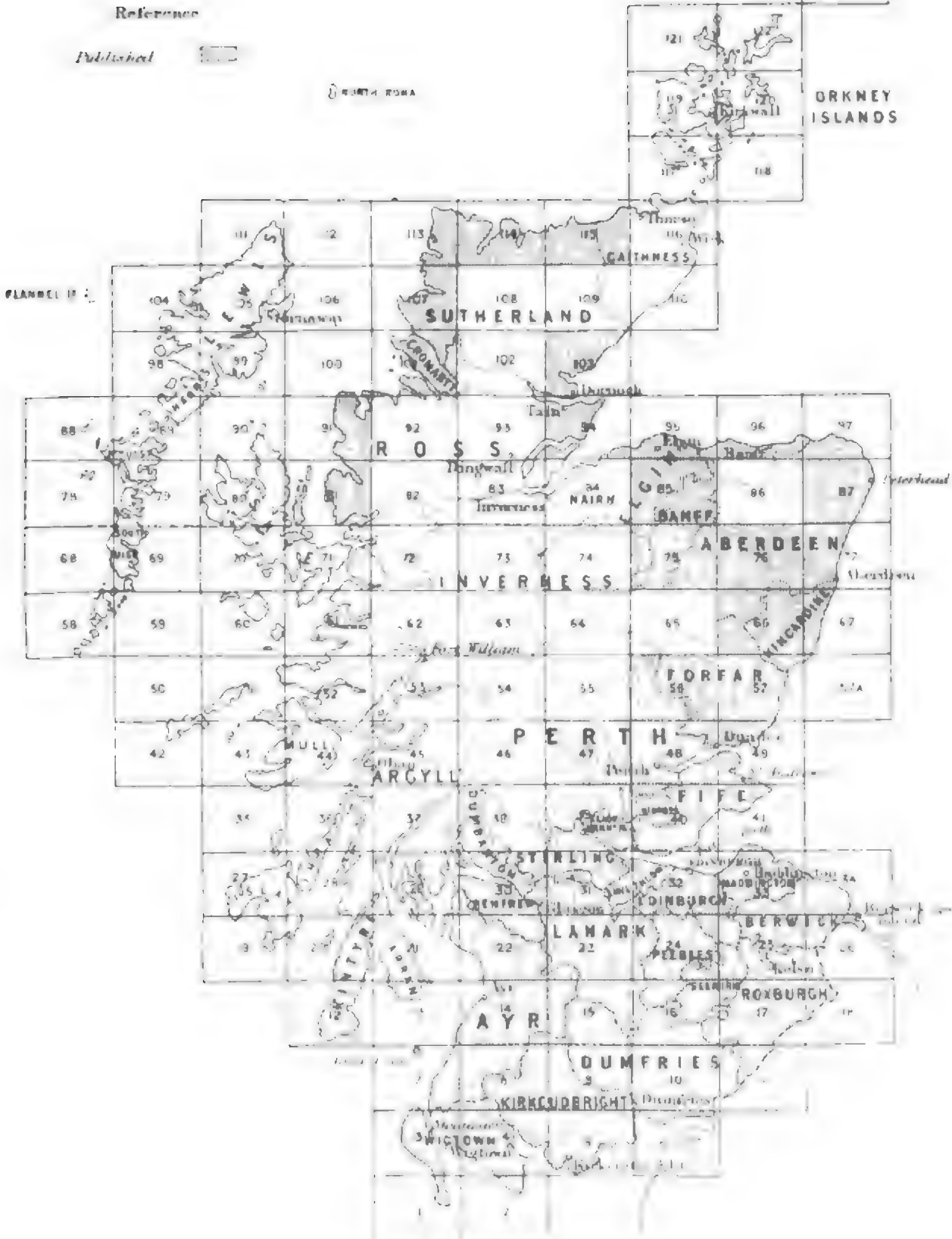


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SUMMARY OF PROGRESS

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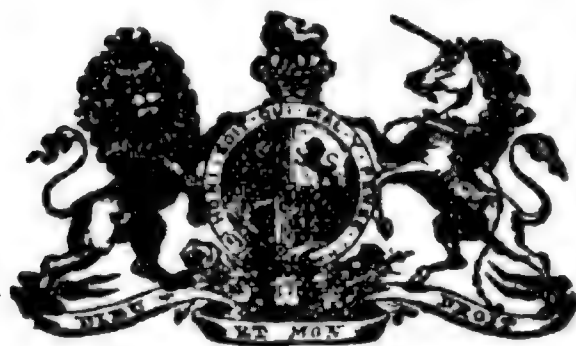
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SUMMARY OF PROGRESS

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PREFACE.

THE following pages contain an account of the more important results obtained by the staff of the Geological Survey during the year 1899 in the field, the museum, and the laboratory. As far as possible, the account of the work of each member of the staff appears as it has been reported by himself. In regard to the field-work, a preliminary statement is given to show the general distribution of the mapping in each of the three kingdoms. This is followed by a narrative of the work of the past year in the various geological formations, beginning with the oldest.

Among the more noteworthy of these researches the following may here be referred to:—The investigation of the igneous rocks of part of Argyllshire, and particularly the examination of the olivine-monzonites and other more or less basic rocks round the Beinn Bhuidhe granite; the detection in the island of Arran of what are probably Arenig rocks with volcanic intercalations, such as have been already observed at various places along the southern edge of the Highlands; the establishment of the eruptive nature of what were believed to be tuffs and agglomerates in the south-east of Ireland; the closer determination of the stratigraphy of the probably Silurian rocks of Cornwall; the application of the knowledge obtained during the revision of the North Staffordshire coal-field to the recognition of the stratigraphical position of the Coal-measures under the younger formations of the centre of England; the important discovery of Rhætic strata and fossils in the island of Arran; the petrographical researches among the volcanic rocks of the Exeter district and among the so-called “ashes,” “green-stones,” and “felstones” of the east and south of Ireland; and

the detection of phosphatic nodules with traces of probable cell-structure in the Torridonian rocks—the earliest indications of organised existence yet met with in Britain.

Some of these results have important economic bearings. The practical application of the work of the Survey continue to be much sought after by public bodies and by the public generally. A brief reference to this branch of the work, to which a large amount of time and labour is devoted by the officers of the staff, will be found in Part IV. of the present Summary.

Attention may likewise be called here to the Catalogue of Fossil Types and Figured Specimens, inserted as an Appendix. This list is the first of a series which is in preparation to illustrate the contents of the Palæontological Galleries of the Museum.

ARCH. GEIKIE,
Director-General.

*Geological Survey Office,
Jermyn Street, London
15th May, 1900.*

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SUMMARY OF PROGRESS

OF THE

GEOLOGICAL SURVEY

FOR 1899.

Several changes have taken place in the staff of the Geological Survey in the United Kingdom during the past year. MR. H. H. HOWELL, who joined the service as far back as 1850, when SIR HENRY DE LA BECHE was Director-General, reached the age-limit of sixty-five years on 13th July, and then retired. His office of Director for Great Britain has not been filled up, pending a consideration of the future organisation and work of the Survey, but in the meantime MR. H. B. WOODWARD, F.R.S., is provisionally entrusted with the duties of Acting-Director for England and Wales, and MR. JOHN HORNE, F.R.S., with those of Acting-Director for Scotland.

MR. F. J. BENNETT, who entered the Survey in 1868, has had to resign his appointment in consequence of ill-health. The vacancy thus caused among the Assistant Geologists has been filled up by the appointment of MR. E. E. L. DIXON, B.Sc., A.R.C.S.

In order to press forward the revision of the North-Staffordshire coal-field and the country around it, which is much required in the interests of the coal industry, MR. Pocock was transferred last year from Scotland to take part in that work, and has been engaged continuously upon it since the spring.

I.—FIELD WORK.

The field-work in each of the three branches of the Survey has been continued along the same lines and in the same districts as were described in the *Summary of Progress* for 1898. A brief outline of its general distribution will first be given here, and the detailed results obtained will be more fully stated in subsequent pages (p. 6, *et seq.*).

ENGLAND AND WALES.—The revision of the coal-fields and of the counties where the superficial formations had not previously been mapped has been steadily prosecuted.

Leicester-
shire, North
Staffordshire,
Derbyshire,
Cheshire, and
Shropshire.

Thus in the counties of Leicestershire, North Staffordshire, Derbyshire, Cheshire, and Shropshire, considerable progress has been made with the examination of the coal-fields, and with the mapping of the surrounding tracts which come into the sheets of the one-inch map that contain these coal-fields. The work has been carried on under the general supervision of MR. FOX-STRANGWAYS, by MR. GEORGE BARROW, MR. W. GIBSON, MR. T. I. POCKOCK, and MR. C. B. WEDD. An area of $199\frac{1}{2}$ square miles has been mapped, with 1,341 miles of boundary-line, of which 789 represent the sub-divisions of the superficial formations, or Drifts. The Survey of the North Staffordshire coal-fields is now nearly completed. That of the Pottery coal-field is finished, and the map is being prepared for the engraver. The Survey of the Cheadle coal-field has also been finished, with the exception of a few patches of obscure ground. The re-survey of eastern Leicestershire has likewise been extended into a tract where the Drifts had not previously been mapped.

Middlesex,
Hampshire,
Dorset,
Wilts.

The revision of the southern counties and the mapping for the first time of the superficial deposits of that wide region has been continued along the same lines that were sketched in the last *Summary of Progress*. The additional duties at present undertaken by MR. WOODWARD have rendered it expedient to relieve him of some of the supervision of field-work hitherto entrusted to him. Accordingly the mapping in Dorsetshire, Hampshire, and Middlesex has been placed under the charge of MR. CLEMENT REID, F.R.S. MR. CAMERON has continued his work in the Thames Valley. MR. DIXON, who entered on his duties in July, was first trained in the Survey methods of field-work by MR. REID, and since then has been engaged on the Chalk, Eocene, and Drifts of the County of Dorset. MR. REID himself, besides supervising the work of his colleagues, has continued his revision of the Hampshire Tertiary Basin and of the surrounding tracts of Wilts and Dorset. The total area surveyed by him and his colleagues amounts to $181\frac{1}{2}$ square miles, with 562 miles of boundary-lines, of which 407 relate to the Drift.

Oxfordshire.

In Oxfordshire, MR. J. H. BLAKE, from Oxford as a centre, has surveyed an area of 48 square miles, with 192 miles of boundary, including 167 miles of Drift-lines.

Devon and
Cornwall.

In Cornwall and Devonshire the re-survey has been continued by MR. S. B. WILKINSON, MR. W. A. E. USSHER, and MR. J. B. HILL. They have surveyed an area of $135\frac{1}{2}$ square miles, and have traced 397 miles of boundary, whereof 152 miles belong to the Drift. The work has been carried on westwards from Plymouth to the neighbourhood of Liskeard and Looe. Near Falmouth the coast and creek sections have been studied in detail along an extent of 68 miles, and the sections along the railway to Truro, and eastwards towards St. Austell have been examined in order that the stratigraphy of the district may be more clearly understood. A large part of the Land's End region has now been surveyed. Both MR. WILKINSON and MR. HILL were occupied during part of the year in the survey of certain areas in Scotland, on which they had been engaged previous to

their transference to Cornwall, and which it is desirable that they should themselves complete.

MR. G. W. LAMPLUGH, having completed the mapping and the ^{Sussex.} Memoir of the Isle of Man, was transferred to the south of England, where his intimate knowledge of the Lower Cretaceous rocks of Yorkshire and Lincolnshire can be made available in the revision of these formations in Sussex and Kent, and in the preparation of a monograph descriptive of the Lower Cretaceous rocks of England. He has accordingly begun the re-survey of Sussex, where he has mapped an area of 50½ square miles, with 197 miles of boundary, including 66 miles of Drift-lines. Much of his time in the early part of the year was occupied with his Memoir on the Isle of Man, which has now gone to the printer. He was engaged also in an examination of the cores obtained from the deep borings and shafts that have been made in the search for coal in the south-east of England.

In the South Wales coal-field the re-survey has been carried on under the general supervision of MR. STRAHAN, with the co-operation of MR. R. H. TIDDEMAN, MR. W. GIBSON, and MR. T. C. CANTRILL. An area of 104 square miles has been mapped, with 577 miles of boundary-line (263 Drift). As MR. GIBSON, during the greater part of the year, was occupied in the re-survey of the North Staffordshire coal-field, his services were only given for a short time to the South Wales Coal-field in order to complete some colliery information. In future he will be engaged continuously in the re-survey of the Midland coal-districts. In South Wales the field-work has been carried on as far westwards as the neighbourhood of Swansea. The first memoir on the district, being the Geology of the country around Newport, in Monmouthshire, written by MR. STRAHAN, has now been published.

In England and Wales the total area surveyed in 1899 has amounted to 719 square miles, and the number of miles of geological boundaries to 3,266, of which 1,844 belonged to the mapping of the superficial deposits. The ratio of area to boundary-lines is thus almost exactly similar to that of the previous year, every square mile of surface having involved, on the average, the tracing of about four miles and a half of boundary-lines.

MR. JUKES-BROWNE has been occupied in revising the proofs, in slips and in pages, and in preparing the index, of the first volume of his Memoir on the Upper Cretaceous Rocks of England. He has, moreover, completed the MS. of the second volume dealing with the various divisions of the Chalk.

MR. WHITAKER, F.R.S., has been good enough to communicate records of nineteen wells and borings, representing 3,867 feet of strata.

A number of note-books containing records of pits and quarries and of well-sections, together with some MS. geological maps, which belonged to the late SIR JOSEPH PRESTWICH, have been presented by LADY PRESTWICH.

SCOTLAND.—The amount of field-work in Scotland has been somewhat reduced owing to several causes, among which the chief are the loss of MR. POCOCK'S services by his transference to the English staff, the detention of MESSRS. PEACH and HORNE in the office until the end of June in connection with the completion of a large Monograph on The Silurian Rocks of Scotland, and the removal of MR. HORNE in the autumn from the field to take charge of the office-work in Edinburgh. The mapping has been continued in the same districts as were mentioned in the last *Summary of Progress*.

Aberdeenshire. In Aberdeenshire, MR. BARROW mapped 34 square miles, with 121 miles of boundary; and in the same county MR. CUNNINGHAM-CRAIG reports $49\frac{1}{4}$ square miles, with 268 miles of boundary.

Argyllshire. In Argyllshire, MR. SYMES surveyed 31 square miles, with 204 miles of boundary; in the island of Jura in that county MR. WILLIAMSON mapped 31 square miles, with 69 miles of boundary, and in Islay he traced 119 miles of new boundaries in ground previously surveyed. In the same county also MR. WILSON mapped $7\frac{1}{2}$ square miles, with 14 miles of boundary, and MR. KYNASTON $61\frac{3}{4}$ square miles, with 414 miles of boundary.

Arran. In the island of Arran, MR. GUNN surveyed $9\frac{1}{2}$ square miles, with 84 miles of boundary.

Dumbartonshire. In the county of Dumbarton, MR. CRAIG traced 72 miles of new boundaries in ground mapped some years ago.

Invernessshire. In the county of Inverness, MR. HORNE in Strath Nairn mapped $3\frac{3}{4}$ square miles, with 11 miles of boundary; in the west of the same county, south-east of Glenelg, MR. CLOUGH surveyed $37\frac{1}{2}$ square miles, with 416 miles of boundary. MR. WILSON, stationed in the Fort William district, completed an area of $42\frac{1}{2}$ square miles, with 137 miles of boundary, and MR. HINXMAN, with Beaully as a centre, an area of 30 square miles, with $168\frac{1}{2}$ miles of boundary. In the island of Skye, MR. HARKER mapped $29\frac{1}{4}$ square miles with $540\frac{1}{4}$ miles of boundary, or upwards of 18 miles of boundary in every square mile surveyed.

Perthshire. In Perthshire, MR. WILSON surveyed 15 square miles with 20 miles of boundary, and MR. CUNNINGHAM-CRAIG traced $105\frac{1}{2}$ miles of fresh boundaries in ground previously mapped.

Ross-shire. In the county of Ross, with Kinlochewe and Dingwall as centres, MR. PEACH mapped $52\frac{3}{4}$ square miles and 267 miles of boundary; MR. HORNE in the west part of the Fannich Forest surveyed $6\frac{1}{4}$ square miles with 36 miles of boundary; and MR. GUNN, in the mountainous part of the Braemore and Fannich Forest, mapped $10\frac{1}{2}$ square miles with 87 miles of boundary. In the eastern part of the same county, from his station at Beaully, MR. HINXMAN surveyed 29 square miles with $102\frac{3}{4}$ miles of boundary.

Stirlingshire. In the county of Stirling, MR. CUNNINGHAM-CRAIG traced $29\frac{1}{2}$ miles of new boundary-lines along the border of the Highlands.

The total area surveyed in Scotland during the year has been $480\frac{1}{2}$ square miles, and the total aggregate length of boundary-lines traced amounts to $3,285\frac{1}{2}$ miles. Each square mile mapped

has thus involved on the average the tracing of 6·84 miles of boundary.

IRELAND.—The whole of the one-inch map of this country having been completed and published, the field-work of the small staff retained for the purpose consists in revising the sheets of the map, and bringing it abreast of the present state of our knowledge of the structure of the country. Many years have elapsed since the maps of the eastern and southern counties were completed, and much new light has been thrown on the rocks during the interval.

The first revision has consisted in a re-examination of all the Silurian tracts in Ireland, with the view of separating the Lower from the Upper division, and of bringing the petrography of the ground up to date. It has also included the tracing of the superficial deposits in certain counties which were mapped at the beginning of the history of the Survey, but in which, as in England at the same time, these deposits were neglected.

In Wicklow MR. NOLAN has continued the mapping of the Drifts and the peat. In the same county, as well as in Counties Dublin and Wexford, some interesting and important re-examinations of the igneous rocks have been made by MR. EGAN and MR. MCHENRY, assisted in the petrographical work by MR. SEYMOUR. In addition to this region, further attention was given to some of the ground to the north of Dublin, with the view of obtaining material for completing the petrographical determinations necessary to allow the revised edition of the maps to be prepared and published. Thus the tracts of igneous rocks in the districts of Slane and Balbriggan were examined by MESSRS. MCHENRY and SEYMOUR, while a careful study on the ground was made of the dykes along the coast of Co. Down by MESSRS. EGAN and SEYMOUR.

In Co. Waterford MR. KILROE has completed the task assigned to him of tracing the boundary between Lower and Upper Silurian rocks. He has necessarily been much occupied by the eruptive rocks which form so large and important a part of the geological structure of that part of Ireland, and he has been able to effect changes of consequence in the representation of them upon the maps.

In connection with the revision of the Silurian rocks, MR. CLARK has continued to search the strata for fossils with the view of furnishing palæontological evidence for the mapping. Last year he was engaged in the Counties Clare, Tipperary, Kilkenny, Wexford, and Waterford. Near the granite of Leinster the rocks proved unfossiliferous, but near New Ross and Duncannon fossils were found that pointed to a Lower Silurian age. The well-known fossiliferous localities of Waterford had already been fully examined, and collections of specimens from them have long been displayed in the Survey cases in the Dublin Museum of Science and Art.

In the following account of the chief scientific and economic

results obtained by the Survey during the past year, the various geological formation of the British Isles will be taken in succession, beginning with the oldest.

PRE-CAMBRIAN.

Ross-shire.

The mapping of the displaced masses of Lewisian gneiss and the crystalline rocks embraced in the "Moine series," which was described in last *Summary of Progress*, has been continued in the counties of Ross and Inverness. The district around Loch Fannich, westwards to Loch Maree, and eastwards beyond Lochs Luichart and Garve, has been further investigated by MESSRS. PEACH, HORNE and GUNN.

MR. PEACH, to whom was assigned the more westerly and easterly portions of the ground, has furnished the following report of his field-work.

Kinlochewe
and Fionn
Bheinn (Mr.
Peach.)

From the station of Kinlochewe on Loch Maree he worked out some of the details of the complex folds into which the Lewisian gneiss, the basement beds of the Torridonian, and the Cambrian formations are thrown in the mass of rock which overlies the "Glen Logan" thrust plane to the north of Kinlochewe. Besides being much puckered and folded, these strata are also traversed by minor thrust-planes and faults, which add greatly to the difficulty of unravelling their structure. Two small dykes of lamprophyre were mapped, which have been intruded since the period of the movement.

From the same centre Mr. PEACH also completed an area of about twelve square miles, between Loch Rosque and the River Bran on the south, and the Leckie Burn which joins the Kinlochewe River on the north. The western part of this ground is a high table land, with an average height above sea-level of over 1,000 feet, but deeply trenched by valleys, while the eastern part rises into the mountain mass of Fionn Bheinn, which attains a height of over 3,000 feet, and forms a conspicuous landmark.

The rocks of the tableland consist chiefly of quartzose granulitic Moine-schists many of which are of the typical micaceous flaggy character so well developed in the original Moine district of Sutherland. Towards the east, however, they occur in more massive beds. They alternate in varying degrees with dark biotite-schist over the greater part of the tableland. Fionnbheinn, on the other hand, so far as it has yet been mapped is almost entirely composed of muscovite-biotite-gneiss or schist, together with subordinate bands and lenticles of quartzose granulitic schist, and a few thin sill-like layers of garnetiferous epidiorite or hornblende-schist. The line of junction of the more quartzose Moine-schists and biotite-schists with the muscovite-biotite-gneiss has been traced across the ground now referred to. To the north it joins up with the line which was

drawn by MR. POCKOCK, and was referred to in the *Summary* for last year.* The continuation of the same boundary has been traced by MR. HORNE and MR. GUNN far to the north along the western slopes of the Fannich Hills into the plain beyond. Kinlochewe and Fionn Bheinn (Mr. Peach.)

The ground mapped last year by MR. PEACH has a length of about five miles from west to east across the strike of the beds. Throughout its extent the apparent dip of the strata is towards the east, at angles varying from 20° to 40°. This arrangement arises from their being thrown into a series of isoclinal folds. Many of the minor folds can be seen in dip section, while the existence of others of greater amplitude can be demonstrated by following the layers of biotite-schist round the ends of the folds, where the "pitch" allows, so that what might appear to be successive outcrops of different bands of biotite-schist have thus been proved to belong to one and the same band. Further, there is strong presumptive evidence that, notwithstanding that the dip of all the structures is towards the east, there is a generally descending order of succession of the strata in that direction. The apparent dip of the quartzose granulites beneath the muscovite-biotite-gneiss of Fionn Bheinn is due to their forming the western limb of a much-compressed and overthrown anticlinal fold of great width. In the mountain itself, no core of rock of the type of the Lewisian gneiss has been observed; but granulitic, hornblendic and biotitic gneisses, like those which have already been described from Sgurr Mhuillín and Loch Luichart,† and surrounded by Moine schists and muscovite-biotite-gneiss, crop out in the stream which drains the southern slopes of Meall an Thuinn Bhain at the extreme eastern limit of the area surveyed last year.

From Dingwall as a centre MR. PEACH was able to reach the ground between Auchterneed and Loch Luichart and to continue the work well into the southern flanks of the Ben Wyvis mountains. Loch Luichart and Garve. (Mr. Peach.) The same groups of rock as were mapped in the previous year‡ were again met with—(a) a series of granulitic, hornblendic and biotitic gneisses, which, with dyke-like masses of peridotite, occur on the crests of some of the anticlines, and are presumably Lewisian; and (b) an overlying series made up of schists or gneisses of two types, the prevailing one being a granulitic quartzose schist with more or less mica (Moine-schist) and muscovite-biotite gneiss. Thin bands of garnetiferous epidiorite and hornblende-schist, that occur as sills both in the Moine-schist and the muscovite-gneiss, appear to have been intruded into the rocks prior to their foliation and certainly before their plication, since they follow the numerous folds into which these are thrown. In addition to the sills of hornblende-schist the only other foliated igneous rock associated with the schists is a sill-like mass of augen-gneiss or granite like that mentioned in the last *Summary*. This sill may possibly be

* *Summary of Progress* for 1898, pp. 15-17.

† *Op. cit.*, p. 7.

‡ *Op. cit.*, pp. 7-11.

Loch
Luichart and
Garve.
(Mr. Peach.)

continuous with one of those crossed by the railway near Loch Luichart, though the actual connection between them, if it exists, is masked in the intervening ground by drift. Its outcrop has been traced from near the road between Loch Luichart and Corriemoillie north-eastwards under the Old Red Sandstone outliers of Ben a Bhric and Ben nan Cabag across the watershed towards the outcrop mapped by MR. GUNN, who has followed it into the well-known exposure at the bridge which crosses the Blackwater, near Inchbae. From its prominence, its mode of weathering, and its prolonged extent, it has supplied a vast number of boulders which have been dispersed far and wide over the basin of the Moray Firth, and afford excellent evidence of the movement of the ice which transported them.

One thin dyke of lamprophyre, nowhere more than 10 feet broad, has been traced in an east and west direction for several miles a little to the north of Loch Luichart. This is the only unfoliated igneous rock met with. Although the date of its intrusion cannot be directly determined, it may be inferred from the fact that a mica-trap of somewhat similar type was found to cut an outlier of the breccia of the Old Red Sandstone to the east of Loch Garve.* It is probable that the lamprophyres of this district are of later date than the basement beds of the Old Red Sandstone.

Fannich -
Forest.
(Mr. Horne.)

The mapping of the mountainous region of the Fannich Forest, of which some account was given in the last *Summary of Progress*,† was again resumed by MESSRS. HORNE and GUNN, the former working southward, the latter northwards towards Loch Broom.

MR. HORNE reports that from his station at Cabuie to the west of Loch Fannich he surveyed ground along the southern slopes of Sgurr Breac and A'Chailleach (3,276 ft.), the western peaks of the Fannich group, westwards to near An Groban and southwards to the Cabuie river. This tract lies to the south of the area mapped by MR. GUNN, and to the north of that mapped by MR. Pocock during 1898. The crystalline schists met with in it belong to the same well-defined groups, which have been previously described, but of which a brief enumeration may be here repeated for the sake of clearness in the following descriptions of the latest results of the field-work.

1. Acid gneiss, with basic lenticles and bands of hornblende-schist, epidiorite and garnetiferous hornblende-rock, resembling certain types of Lewisian gneiss.

2. Massive biotite-gneiss, highly garnetiferous in places with irregular masses of garnetiferous hornblende-rock. (Meall an't Sithe and Meall Dubh gneiss.)

3. Granulitic quartzose schist or gneiss — quartz-biotite-granulite or Moine-schist. (Meall a' Chrasgaidh rock.)

4. Flaggy biotite schist with small garnets.

GROUP 1.—The members of Group 1 enter the area mapped by MR. HORNE in 1899, along the western slope of A'Chailleach

* *Summary of Progress* for 1898, p. 11.

† *Op. cit.*, pp. 11-17.

between the contour-lines of 2,250 and 2,750 feet, where the pink Fannich granulitic acid gneiss with folia and eyes of felspar, and bands of Forest. (Mr. Horne.) epidiorite and hornblende-schist form a well-marked belt, readily distinguished from the garnetiferous muscovite-biotite-gneiss (group 2) both above and below it. Here the acid gneisses and the associated basic masses have a gentle easterly dip at angles varying from 10° to 15° . Owing to so gentle an inclination the members of this group present a highly sinuous outcrop for about six miles in the mountainous tract lying to the north-west of Cabuie. Along this outcrop numerous stream-sections show the lithological characters of the rocks. Upon the crest of the dividing ridge (An Sguman) for nearly a mile the overlying garnetiferous muscovite-biotite-gneiss has been removed by denudation, and the acid gneiss with its basic bands is laid bare in gentle undulations; the more prominent basic bands being repeated in the successive folds on the crest. There can be little doubt that the more massive basic bands, which here consist of green hornblende and plagioclase felspar, are intrusive in the acid gneisses, for they seem to transgress its foliation planes. In addition to the larger basic masses, thin strips of hornblende-schist and small lenticles and knots of hornblende-rock in the acid gneiss recall familiar features in the Lewisian gneiss of the north-west Highlands. The acid gneiss associated with these basic masses is coarsely granulitic and highly quartzose, with folia and eyes of felspar, as well as some biotite and muscovite. Sometimes it is finely striped and granulitic, with marked linear foliation, approaching the quartzose granulites of the Moine type. This latter type is frequently developed along the line of junction with the coarse garnetiferous muscovite-biotite-gneiss (group 2).

GROUP 2.—The characteristic muscovite-biotite-gneiss of this sub-division both overlies and underlies the belt of acid gneiss just described, in the tract to the north-west of Cabuie. Both outcrops are believed to be repetitions of the same band due to folding. The overlying mass is well exposed on the higher part of A' Chailleach, and two small outliers of the same material are visible on the crest of An Sguman, between the Cabuie river and Abhuinn Nid. The underlying outcrop has been traced from the western slope of A' Chailleach, where this rock is exposed between the contour-lines of 2,000 and 2,250 feet south-eastwards to the mouth of the Cabuie river and the shores of Loch Fannich. Throughout this ground the rock varies considerably in character. The normal type consists of large plates of biotite and muscovite with garnets and quartzo-felspathic material in thin veins and knots, presenting the characters of a coarse biotite-gneiss. Sometimes along the same line of outcrop the pegmatites disappear, the plates of mica become smaller, and the rock merges into a schist in which biotite and muscovite are the chief constituents, or a fine-grained mica-schist. Occasionally irregular masses of garnet-hornblende-rock appear in the garnetiferous gneiss, as for instance near the base

Fannich
Forest.
(Mr. Horne.)

of the more easterly outlier on An Sguman, and in the outcrop underlying the belt of acid gneiss.

GROUP 3.—The flaggy granulitic quartz-schists, which are the distinguishing feature of this group, appear on the col to the west of A' Chailleach where they rise from underneath the garnetiferous gneiss (group 2), and dip to the east at an angle of 10° . The boundary line between these two groups is there well defined, and it has been traced south-eastwards along the south slope of An Sguman to a point on the Cabuie river about a mile west from Loch Fannich, where it enters the ground mapped in 1898 by MR. POCOCK. It was last year followed by MR. PEACH along the west slope of Fionn Bheinn towards Achnasheen.

GROUP 4.—Not far below the junction line of the quartz-schists with the garnetiferous muscovite-biotite-gneiss, on the south-west slope of An Sguman, a band of flaggy biotite-schists with small garnets appears, with a similar gentle dip to the east. These schists are likewise underlain by flaggy quartzose schists of the Moine type. At present it is uncertain whether this group corresponds to the biotite-schists of Sgurr Mor Fannich, though lithologically the rocks resemble each other. The result of the mapping of the Fannich mountains proves that the groups of crystalline schists identified by MR. GUNN on the northern slopes of that range are repeated on both limbs of a fold of great amplitude, in which the various groups seem to preserve the same relative position towards each other. It further appears from the gentle inclination of the various groups in the western part of the area, at least, that the axial planes of the folds must lie at comparatively low angles.

One instance of intrusive rocks later than the movements which determined the foliation and plication of the schists was found in the corrie at the head of Abhuinn Nid. It consists of a thin dyke of lamprophyre.

Loch
Fannich to
Loch Broom.
(Mr. Gunn.)

The ground surveyed last year by MR. GUNN lay near the watershed between Loch Fannich and Loch Broom. High, craggy, and difficult of access, it rises for the most part to a height of more than 1,500 feet, while three of the hills included in it exceed 3,000 feet. The greater part of his mapping lay around Loch a' Bhraoin. The same four groups of rock which he had established in previous years, and which, as above stated, were followed by MR. HORNE on the southern side of the watershed have been further traced by MR. GUNN on the north side. He furnishes the following notes of the development of these rocks in the ground mapped by him last year.

The Biotite-schist of Sgurr Mor Fannich (No. 4) makes up but a small portion of the area. In several places it appears to be much more plicated than the quartz-schists which border it on either side. This difference may be due to the rock having been of a softer nature, so that it yielded more readily to pressure than the hard siliceous rocks. In the streams to the north-west of the head of Loch a' Bhraoin, a fairly thick band of biotite-schist probably represents this rock or is a part of it. This band,

however, has not yet been traced continuously over Creag Rainich, and connected with the biotite-schist near the Fain Inn. On the watershed to the south-west of A'Chailleach a band of biotite-schist, apparently much thinner than the last, which has been followed northwards into the streams that run into the head of Loch a' Bhraoin from the south, is not only much thinner than the Sgurr Mor rock appears to be, but also lies apparently on a much higher horizon, not far below the upper boundary of the Meall a' Chrasgaidh rock (No. 3). This band of biotite-schist has been followed by MR. HORNE for a long distance on the south side of the watershed. Its relation to the Sgurr Mor rock cannot yet be decided.

Loch
Fannich to
Loch Broom.
(Mr. Gunn.)

The band of flaggy quartz-schist of Meall a' Chrasgaidh (No. 3) presents a typical Moine-type, and occupies the upper part of the valley of the Strathbeg River which runs into Little Loch Broom. Its component members dip to the east-south-east and south-east, but near Creag Rainich, at the head of the valley, they curve round and run across the ridge to the south, while the inclination changes to a northerly direction along the north side of Loch a' Bhraoin, so that the band forms a synclinal fold, in the centre of which, and forming the highest ground, lies the garnetiferous gneiss (No. 2). Numerous sections of these flaggy quartz-schists may be seen in the small streams (which are far more numerous than would appear from the map) on the north side of Loch a' Bhraoin. The numerous streams on the south side of the loch, near its head, run for the most part in glacial drift and do not afford good sections of the rocks below. No intrusions of igneous material have been met with in the Meall a' Chrasgaidh rock, and it seems also to be almost entirely devoid of pegmatites.

The garnetiferous gneiss of Meall an't Sithe (No. 2) forms an outlier on the ridge north of Loch a' Bhraoin, extending for three miles, from Meall an't Sithe nearly to Creag Rainich. As just mentioned, it lies in the centre of a syncline, which is probably broken by a fault along its south-eastern side near the loch. The rock is often massive in appearance, and is largely made up of small bands of white or light-coloured pegmatites, which for the most part coincide with the foliation-planes. Irregular bosses and sills of a basic rock, for the most part hornblendic, are often met with. They are crowded with garnets, while large garnets are likewise distributed generally through the mass of the gneiss.

Near the northern edge of the mass, bands of a very acid schist or gneiss occur, quite different in character from the bulk of the rock. The largest and most important of these, seen about a mile west of the top of Meall an't Sithe, is almost certainly an infold of the siliceous rock (No. 3) below. Good sections occur in the crags all along this northern boundary, but perhaps the finest continuous exposure has been laid open in the crag on the south side of Loch a' Bhraoin from near the burn called Allt a' Goibhre, which issues from Toll an Lochain, round to Allt Brebaig. At the latter locality, the rock near its upper boundary

Loch
Fannich to
Loch Broom.
(Mr. Gunn.)

is in places comparatively free from garnets, is more evenly foliated than usual, and contains abundance of white mica, with very little biotite. A good exposure of the garnetiferous gneiss is visible in Allt na Goibhre, but to the westward the boundary between it and the siliceous flags is much obscured by drift for a long distance, only small isolated sections occurring till, on the west side of A'Chailleach, the rock again appears at the surface.

In Allt na Goibhre above the uppermost of two thick bands of acid gneiss, the Meall an't Sithe garnetiferous gneiss, or a rock very similar to it, again comes out in great force. It occupies the whole of the valley, spreads over the bounding ridges on either side, and forms all the upper parts of A' Chailleach and Sgurr Breac with the high ground between them, thus occupying all the watershed for a distance of two miles. On these hills, owing to the comparative absence of the small pegmatitic bands, the rock occasionally approaches more in character to an ordinary biotite-schist.

Considerable additions were made last year to our knowledge of the physical structure and composition of the acid gneiss (No. 1) in the area mapped by MR. GUNN. The rock is typically developed at the head of Allt Brebaig, between Sgurr Breac and Sgurr nan Clach Geala, where the coarse-grained grey acid gneiss has a marked north-west strike. In general, it is of a very acid type: some granulitic parts of it, indeed, might at first sight be confounded with the siliceous Meall a' Chrasgaidh rock, were it not for the basic bands associated with the gneiss. A grey granulitic rock with marked linear-foliation, which occurs in the eastern branch of Allt Brebaig, 1,500 yards north-east of Sgurr Breac, has been found by MR. TEALL, on microscopic examination, to be composed of quartz, felspar, and two micas, with sphene as an accessory. Not far to the west, in the burn, called Allt nan Eilig, a well-banded grey and cream-coloured rock occurs, which MR. TEALL calls a fine-grained granulitic schist. His description of its appearance under the microscope is—No. 7509:—Epidote (grains and crystals of uniform dimensions in the different directions and occasionally containing brown cores, orthite?), pale green pyroxene, hornblende (scarce), water-clear felspar, and quartz, forming an irregular mosaic (individuals varying in size), sphene as an accessory: epidote pyroxene-granulite.

About a quarter of a mile farther up the same stream a specimen from one of a group of broad bands of black, coarse-grained, massive rocks of a basic character is described by MR. TEALL as a granitoid aggregate of green or greenish-brown hornblende and plagioclase (oligoclase); sphene as an accessory. These basic bands appear to have all the characters of true intrusive dykes and bear the same relation to this acid gneiss as the epidiorite dykes do to the normal Lewisian gneiss. They have been traced for about two miles in a north-west and south-east direction. Their total width varies between 100 and 200 yards, and in some places seems to consist wholly of dyke-material, while in others thin strips of acid gneiss

divide the whole into distinct bands. A somewhat different type of basic rock is also met with in the same ground; lenticles of basic material—irregular lumps, and thin bands of hornblende-schist which apparently bear the same relation to the acid gneiss of the district as the earlier basic rock does to the Lewisian gneiss.

Loch
Fannich to
Loch Broom.
(Mr. Gunn.)

The rocks of this area are much plicated. A beautiful example of folding on a rather large scale occurs in the crags to the south-west of Sgurr nan Clach Geala. In ascending a stream three quarters of a mile south-south-west from the hill-top, we come upon a band of diorite about 30 yards broad, and 300 yards farther up, upon another band 70 yards wide, having a strip of gneiss 50 feet wide in the middle of it. The foliation of all the gneiss hereabouts dips uniformly and steeply towards east-north-east. As the broader band is traced northwards for about half a mile in the great precipice of Creag a' Fhuarain, the included strip of gneiss disappears and the whole then becomes one dyke, 100 yards or more in width. The smaller band widens out somewhat also as it is followed northward into the same crag, where the two bands are seen to form the two separate limbs of one isoclinal fold which curves round and spreads out over the crag. The foliation of the adjoining gneiss and the occasional foliation in the dyke itself show this clearly. In one part of the crag the width of the mass of diorite is as much as 800 feet. At the head of Coire Breac, so intense is the folding that the acid gneiss is felted with the garnetiferous gneiss, and both are shot with numerous pegmatites.

No basic igneous rocks have been noticed in the acid bands under A' Chailleach, but two acid bands seen in Allt na Goibhre contain dark basic material. In the uppermost of them some of the basic masses are foliated, and in one striking section the foliation of the acid gneiss cuts that of the included basic rock nearly at right angles—an almost exact parallel to the structure found in the Lewisian gneiss of the Gruinard district.

It is not necessary to allude further to the intrusive igneous rocks as they have been for the most part included in the foregoing account of rocks in which they occur. Those in the acid gneiss are generally diorites or hornblende-schists, while the bosses and sills of basic material associated with the garnetiferous gneiss are generally hornblendic in composition and crowded with garnets. The small pegmatites so generally diffused through the latter rock must generally be considered as segregations from the adjacent rock, and as the results of extreme metamorphism, but it is doubtful if some of the larger pegmatites have had the same origin. On the east side of Toll an Lochain and elsewhere masses of coarse pink and white pegmatite have a dyke-like character, several of them being many feet in breadth and stretching for a considerable distance. They generally run along the strike of the foliation, but some are seen to penetrate both the garnetiferous and acid gneisses. A specimen from Druim Ruadh is composed of large pinkish

Loch
Fannich to
Loch Broom.
(Mr Gunn.)

microcline felspar. Traces of a red lamprophyre found in two places at the northern end of Druim Ruadh, probably belong to a sill or dyke, similar in character to those previously described from this district. Rocks of this character, however, are not common: they have as yet been found in only three localities.

Although in the siliceous and granulitic Meall a' Chrasgaidh rock, no intrusions of igneous rock, and few or no pegmatites are met with, when the upper boundary of this band is crossed, they make their appearance both in the garnetiferous and acid gneisses. The coarsely crystalline character of the rocks and the abundance of pegmatites in them appear to be closely connected, and to result from the same cause—extreme metamorphic action—and only very slightly, if at all, from direct intrusion of igneous rocks. But the metamorphism, if, as is usually taken for granted, it was induced from below, can hardly be due to any alteration of the rocks in their present positions, for highly altered masses overlie others which are less altered. The garnetiferous and acid gneisses, for example, come above the Meall a' Chrasgaidh rock. The metamorphism would thus appear to have occurred when the acid gneiss and the garnetiferous gneiss were below the Meall a' Chrasgaidh rock, and in that case it will follow that notwithstanding the apparently regular order of succession now existing, the rocks are really inverted. Another possible explanation may be offered, viz., that the more highly altered rocks owe their present abnormal position to a lateral thrust, but no trace of anything of this kind has been noticed by MR. GUNN.

Inverness-shire.

District of
Glenelg.
(Mr. Clough.)

The examination of the ground between the Gleann Beag of Glenelg and Loch Hourn has been continued by MR. CLOUGH, who supplies the following notes of his work:—

Like the ground to the north, already described,* the tract surveyed last year, is composed in the main of rocks which seem to belong either to the Lewisian gneiss series or to the Moine-schists. Those believed to form part of the Lewisian gneiss series present very varied characters. They include a considerable proportion of hornblende-schist, hornblende-biotite-schist, eclogite, highly felspathic pink granulitic gneiss, and also some serpentinous and other rocks, which may be of igneous origin. Mixed intimately with these varieties are bands of limestone, kyanite-schist, graphitic calc-silicate seams, and other rocks probably of sedimentary origin. The limestone makes unusually broad outcrops on the south side of the Gleann Beag near Corrary and Balyraid. It is also well seen at other places. Various new localities for the spinels, which occur in the limestone,† have been noticed.

* *Summary of Progress* for 1897, p. 36.

† See *Quart. Journ. Geol. Soc.*, vol. lv. (1899), p. 372. "On Spinel and Forsterite from the Glenelg Limestone." By C. T. Clough and W. Pollard.

In the part of the Lewisian gneiss series between Rudha Mor and Rudha Buidhe a considerable proportion of pale acid gneiss which in hand-specimens greatly resembles some highly-altered felspathic grits, is so much mixed with hornblende-schist, in sill-like bands, lenticles and knots, and also with thin streaks and knots of pegmatitic material, that its true origin is difficult to determine. Some parts of it which can hardly be distinguished from the rest wind round the hornblende-schist lumps. There is likewise occasionally in these lumps a banded structure which ends rather sharply at their sides, as if the pale gneiss, or part of it, had once been in a state of flow since the formation of the banded structure. The intermixture of pegmatitic material is generally less on the coast between Eilean Chlamhuinn and Rudha Buidhe than it is further north-west, and at the same time the sedimentary aspect of the pale gneisses is greater. The pegmatite streaks between Rudha Mor and Rudha Caol, each rarely more than a few inches thick, are so numerous that they make up about half the bulk of considerable exposures of the rock. They consist chiefly of felspar, and often present a granulitic condition. In some parts of the district, particularly near the Moine-schist, between Eilean Mor and Ellanreoch and near Allt a' Ghearr Oir, broad bands of pink granulitic gneiss bear considerable resemblance to the thin granulitic pegmatites just referred to.

District of
Glenelg.
(Mr. Clough.)

In most parts of the area in which the rocks occur that may belong to the Lewisian gneiss, the hornblende-schists and also the eclogites, take the form of sill-shaped sheets and lumps like small laccolites, rarely if ever showing clear evidence of intrusion. In some places, however, certain bands of hornblende-schist behave like dykes. Some of the rocks cut by these dykes are themselves also hornblende-schists, but of a more variable type, and generally coarser in grain than those of the dykes. The earlier hornblende-schists resemble in many respects certain members of the Lewisian gneiss which, when they were mapped in Sutherland were known in the Geological Survey by the name of "early basic rocks," while the later dykes of hornblende-schist more closely resemble foliated dykes of the well-known "Scourie" type. There are also one or two foliated dykes which consist chiefly of hornblende and biotite with little or no felspar. None of the dykes of hornblende-schist have yet been traced up to the edge of or into a Moine-schist outcrop, and therefore it is uncertain what their age may be in respect to the Moine-schist.

The most common rock in the Moine series is a granulitic siliceous schist. A more micaceous variety is mixed in thin parallel seams with the siliceous schist, and in some places forms the predominant rock in outcrops as much as 100 yards wide. Calcareous streaks and lenticles, an inch or two thick, are not uncommon. Thin streaks which contain a considerable proportion of magnetite may likewise be observed. As a rule the Moine rocks contain decidedly less epidote, whether in the form of strings or in small grains scattered through the matrix,

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(Mr. Clough.)

than the Lewisian gneiss rocks, but in a few places they include thin bands so rich in epidote grains as to acquire in consequence a pale yellow colour. Garnets usually abound in the more micaceous bands. One of these bands, extending between Eilean Mor and Rudha a' Chamaish Bhain, is full in many places of thin plates of actinolite lying across the foliation and apparent bedding. Many of the more micaceous bands, for example, this band with the actinolites, and another about a mile south of Ellanreoch, occur next to rocks of the Lewisian gneiss type, but we cannot assert that they all do, and in many places the siliceous granulitic Moine schists are seen in direct contact with the gneiss rocks. It is noteworthy that up to the present time no kyanite has been observed in the micaceous schists which can with certainty be referred to the Moine series of this district, though the mineral is by no means rare in the Lewisian gneiss series.

The Moine rocks which occur in the west part of the area are almost free from pegmatitic material, while many of the Lewisian gneiss rocks of the same district, as already stated, largely consist of, or are permeated by, such material. This contrast, and the absence of bands of hornblende-schist, eclogite, &c., in the Moine rocks of the district, render it comparatively easy in most places to separate the two groups of rocks. In the more easterly districts the Moine rocks are often permeated through and through by pegmatites. The felspar of these pegmatites is not usually in a granulitic condition, but the quartz often is. In some places the pegmatites are as much as 10 or 20 yards wide; in others the pegmatitic material never appears in thick bands, but forms innumerable thin streaks and lenticles from about $\frac{1}{4}$ inch to 2 inches thick, and makes up perhaps half the mass of the rock. The Lewisian gneiss series, where it comes near these pegmatitic Moine rocks, also contains pegmatites of the same kind.

Both in the Lewisian gneiss and in the Moine rocks, occasional bands of biotite granite-gneiss cut the banding of the rocks in which they occur, and these granite-gneisses are also frequently "pegmatized." None of the bands yet observed exceeds 12 or 14 yards in breadth. Their foliation sometimes strikes against their margins and is in the same direction as the foliation in the rocks at their sides.

While the Moine rocks in the western part of the area contain no hornblende-schist, in the eastern part they not uncommonly include partially foliated hornblendic intrusions. Some of these intrusive bands are foliated parallel to their sides and cut both the banding and the foliation of the rocks in which they occur. They are more variable in composition, and generally coarser in grain, than the hornblende-schist dykes, already noticed, which may represent "Scourie dykes." They differ, too, from these inasmuch as they cut all the pegmatites with which they have been seen in contact. They are, therefore, probably of later date. Of three thin slices of these hornblendic intrusions which

have been examined by MR. TEALL, he calls two biotite-amphibolite, and the third hornblende-biotite-schist. District of
Glenelg.
(Mr. Clough.)

As noticed in preceding years, the difference between the strike of the Moine rocks and that of the Lewisian gneiss rocks is rarely sufficiently great to admit of recognition in individual sections, but when exposures at a little distance from one another are compared, the Lewisian gneiss rocks which lie next the Moine rocks are often found at different places to present distinct types. At one locality, about one-third of a mile east-south-east of Rudha na h' Airde Beithe, there is also a distinct difference, amounting, perhaps, to about 12°, between the strikes of the two series of rocks. As the ground there is almost free from drift, in one section the Moine rocks are seen to be lying close to a certain band of hornblende-schist; but to the north-east a pink felspathic gneiss comes in between the Moine rock and the hornblende-schist, and gradually increases to a thickness of perhaps 40 or 50 feet. Still further in the same direction another band of hornblende-schist intervenes between the pink felspathic gneiss and the Moine-schists. These appearances, MR. CLOUGH believes, suggest either that the line between the Moine series and the Lewisian gneiss series here represents a thrust-line, or else that the former is younger than the latter and unconformable to it. Although good indications of stretching have been observed in all the rocks, no important thrust-line has been detected. During the different plications which have affected the district, the junction-line of the two series of rocks may, perhaps, have formed a line of special weakness, but this does not necessarily imply a visible displacement along it.

One of the most remarkable features in MR. CLOUGH'S field-work last year was the discovery of a band,—perhaps never more than 20 feet thick—which has a considerable resemblance to a highly-altered conglomerate or boulder-bed. Most of the larger fragments in it consist of a pink felspathic gneiss, like that which forms a great part of the Lewisian gneiss series in the neighbourhood. The examination of the band is not yet concluded and it would be premature to speak confidently of its character. It lies at the junction of the two great groups of rock near Rudha na h' Airde Beithe.

The prevalent folds in the district are isoclinal, and have limbs hading east or east-south-east, but with frequent twists in the strike into east and west, or north-west and south-east directions. Where the strike is east and west the limbs of the folds hade south. The long extension of the Lewisian gneiss rocks up Gleann Beag, past Balyraid, is owing to the east and west strike in that district. On either side of the gneiss area in this part of the glen extensive outcrops of Moine schist also strike east and west. These can be traced westwards until they twist and acquire a nearly north and south strike. Examples of rocks with north-west and south-east strike occur on the south-east side of Druim Fada, rather more than half a-mile north of the head of the Dubh Lochain of Arnisdale, and on Sgurr na Laire Brice.

District of
Glenegl.
(Mr. Clough.)

Other folds also occur in which the limbs hade in opposite directions. These less acute examples appear often to twist the limbs of isoclinal folds, and consequently to be of later date. For instance, two sets of folds are seen together on the north side of Eilean Tioran, and on the side of the new road nearly half a mile east of Rarsaidh. The earlier folds in both these places are isoclinal with limbs dipping west-north-west or north-west, while the later folds have axial planes dipping gently east. It seems quite possible that the present hade of the limbs of the early isoclines in these localities may have been acquired during the later folding, and that their original hade was east or south-east, like the hade of the limbs of most of the isoclines in the district.

An important group of faults crosses the district in a south-west—north-east direction, from a little west of Eilean Rarsaidh to near Strathchomair. The Moine rocks of Ben Sgriol are thus brought against the Lewisian gneiss rocks on their north-west side for a distance of about a mile and a half. Near Loch na h'Oidheche, the Moine rocks of the eastern part of Beinn a' Chapuill on the north-west side of the faults, come near the Moine rocks of Ben Sgriol on the south-east side. The former are, as already stated, in an excessively altered condition, and thoroughly permeated by pegmatitic material, but the latter are less altered and contain fewer pegmatites. It seems probable, therefore, that the effect of the faults has been either to cause a considerable downthrow to the south-east, or else a large lateral shift which has moved the outcrop of the rocks on the south-east side of the faults, so that they now lie considerably to the north-east of the corresponding rocks on the north-west side.

Since the folding and the production of foliation many intrusions of eruptive material have taken place, chiefly in the form of dykes. The intruded material consists of (1) quartz-felsite, camptonite, mica-trap, or other variety of lamprophyre; (2) basalt, dolerite, and a rock allied to trachyte. About half a mile east of Rudha Mor a small oval boss of gabbro has also been observed. The dykes included in Group 1 have a general east and west or west-south-west and east-north-east direction.* In a considerable number of the lamprophyre dykes apatite crystals are large enough to form a feature in hand-specimens, some of the crystals being about $\frac{1}{2}$ inch long.

Beaully
District.
(Mr. Hinx-
man).

From his station at Beaully Mr. HINXMAN has extended the mapping of the crystalline rocks through new areas of the counties of Inverness and Ross, lying between Strath Conan and Strath Glass. The greater part of the ground surveyed by him is occupied by the Highland schists, with their accompanying igneous intrusions, of which he has prepared the following notice:—

As in the regions already mapped to the south, the schistose rocks of the Beaully district can be separated into two chief

* It may be remarked that the general direction of the same class of dykes on the north side of the Glen More of Glenelg is west-north-west and east-south-east.

groups:—(1) The Muscovite-biotite-gneiss; (2) the Moine schists; representing respectively an originally argillaceous and siliceous series. There is now little doubt as to the sedimentary origin of these rocks, in which the original bedding planes, or colour-bands indicating differences in sedimentation, can still often be traced; while in some of the finer-grained rocks lines suggestive of current-bedding can even be detected.

Beaulieu
District.
(Mr. Hinx
man.)

The Muscovite-Biotite-Gneiss varies in character from a tolerably fine-grained, flaggy, or schistose rock to a coarse, flakey gneiss with corrugated and crumpled folia. The coarser varieties contain much quartzo-felspathic material—possibly of segregative origin—disposed in eyes and strings along the planes of foliation. The rock is also characterized in many parts by large rounded flakes of muscovite lying at various angles to the bands of felted micas (the “spangle-schist” of Badenoch). Garnets are generally abundant, and often of large size. Considerable deposits of garnet sand are found in the streams flowing through areas where these rocks occur. Bands of kyanite-gneiss seen on the spur which runs east from Carn nam Pollan in the north-west corner of the Erchless Forest, lie near the edge of the main mass of muscovite-biotite-gneiss, and are met with also as narrow infolds with the Moine-schists a short distance from the eastern edge of that mass. The kyanite combines with quartz, garnet, and biotite, to form prism-shaped aggregations which project at different angles from the weathered surfaces. The kyanite is clearly a secondary mineral, and as there is apparently no mass of intrusive igneous rock at the surface in this locality, it is probable that the presence of this mineral is due to regional rather than to contact-metamorphism.

The Moine-schist group is composed of a series of fine-grained, thoroughly granulitic, schists and granulites. The relative amounts of quartz and mica (usually biotite) present in the rock continually varies, and the resulting gradation of one variety into another, makes it difficult to draw satisfactory boundary lines between the different types of rock in the field. An attempt, however, has been made to separate out the more siliceous bands—coloured as quartzite on the map—leaving a residuum of undifferentiated quartz-biotite-granulites, gneissose flagstones, and biotite-schists. These granulitic quartzites form lenticular masses with an irregular outline in the gneissose flagstones north-west of Struy, and are also largely developed about Seatwell in Strath Conan. On the summit and slopes of Beinn a Bh'ach Ard several lenticular bands of quartzite, infolded with the coarse muscovite-biotite-gneiss, differ somewhat from the ordinary type. They are highly siliceous, contain little or no mica or felspar, and weather with a snow-white crust. The structure of the rock is coarsely granular and highly crystalline, and very similar to that produced in the siliceous Moine-schists of N.E. Sutherland by igneous intrusions. The rock has the appearance of being in an advanced stage of thermo-metamorphism, and its present condition may possibly be referable to the same causes which have produced the

Beauly
District.
(Mr. Hinx-
man.)

extreme metamorphism of the coarse garnetiferous muscovite-biotite-gneiss and the kyanitic bands which are found in its immediate neighbourhood. With regard to the structure of the ground over which these rocks have been recently mapped, it may be remarked that the schists of Strath Glass are arranged in a series of folds, whose long axes run in a N.N.E.-S.S.W. direction. The folding is almost invariably isoclinal, both limbs of the fold being inclined to the south of east. The quartz-granulites and flagstones that appear from beneath the old red conglomerate W. of Aigas are rapidly folded at high angles, and here, as in several other localities cleavage-planes passing through these minor folds can be detected. These rocks contain thin seams and bands of the muscovite-biotite-gneiss, which is brought in by a major fold at Craigdubh and extends in a line of irregularly lenticular masses northwards to Glen Goibhre. The gneissose flagstones again appear on the further side of this fold and alternate with numerous infolds of granulitic quartzite. These are followed by the main outcrop of the coarse muscovite-biotite-gneiss which crosses the river Farrar at Culligran Falls, and continues northward, forming the high mountain ridge of Beinn a' Bh'ach Ard. The western edge of this belt of gneiss has not yet been mapped, but there is good reason to suppose that it is succeeded by a series of highly siliceous rocks. In the Strath Conan and Glen Orrin district the long axes of the folds seem to be less regular in their disposition and the pitch more variable; so that the boundary-lines will, no doubt, prove to be more complicated than in the region just described.

The only fault of importance in this area is that which has determined the strong line of feature which runs N.N.E. from Erchless Castle along the course of the Allt Mhòr, and the deep hollow in which lies Lochan Fada and the stream at its head. The line of this fault is approximately parallel to the strike of the schists and does not produce any recognisable displacement; but at various points along its course, and especially in the upper part of the stream flowing into Lochan Fada, the rocks are much crushed and brecciated. Its course to the north of Urehan is concealed by peat and drift, but is possibly continued in the line of dislocation which crosses the River Orrin four miles further north, and throws down the Old Red Conglomerate against the schists at Muirton Falls.

The oldest intrusive rocks observed in the Beauly district appear to be a set of bands or sills of amphibolite and hornblende-schist, more or less lenticular in character, which occur on two horizons in the Moine-schists. Their trend is approximately parallel to the general strike of the schists, and the foliation-planes of the latter are continued into the amphibolite. These divisional planes are, however, constantly crossed by the edge of the basic rock, the marginal portion of which is invariably finer-grained and more schistose than the centre. The coarser bands are often highly garnetiferous, and show a tendency to *augen*-structure in the hornblende crystals. These bands may hence be regarded as

representing masses of basic igneous material intruded into the Moine sediments before the development of their present schistose structure. The most easterly group of them is associated with the gneissose flagstones of Strath Glass. A second group has been mapped about Scatwell, in Strath Conan, among the quartzites and quartz-granulites of the siliceous zone. They appear to be more numerous here than in Strath Glass, but in both localities the repetition is probably in a large degree due to rapid folding. A particular sill can often be traced round the end of a fold, and it is possible that at each horizon the number of original intrusions may have been small.

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(Mr. Hinx-
man.)

The acid intrusions in Strath Glass take the form of veins or sills of granite, pegmatite, and felsite. These appear to be later than the movements, which produced schistosity in the Moine-schists, and, except in a very few instances, do not exhibit any parallel structure. The veins of granite and pegmatite are most abundant in the ground between Erchless Castle and Farley Wood, where they form a belt of parallel intrusions running east-north-east, and cutting obliquely across the strike of the schists and hornblende-sills. The smaller branch veins which they give out, often, however, follow the foliation planes of the schists as lines of least resistance. These intrusions, which often measure 20 or 30 yards in breadth, are coarsely crystalline and generally more or less pegmatitic in structure. They are composed of abundant oligoclase, alkali-felspar, quartz, and muscovite. Vermicular pegmatite has been detected under the microscope in a specimen taken from a vein north-north-east of Urchany. The veins here described show no foliation; but a single vein, similar to them in composition, but with marked flaser-structure, occurs at Creag Ard Bheag, 1½ miles north of Erchless Castle. A sill of compact, very hard, brick-red felsite, with the same east-north-east trend, has been traced continuously for nearly 3 miles through the Moine-schists to the north of Struy.

A new point in the work of the past year has been the discovery of a considerable area of solid granite in Glen Orrin, about 4 miles west of Fairburn House. The appearance of numerous granite veins in the schists of Glen Orrin heralds the on-coming of the main mass, which forms an irregular area about a mile and a-half in extent, on the north side of the river. The rock is a medium-grained white or grey granite, wherein the mica, which is not abundant, is usually biotite, muscovite being also sometimes present in small quantity. Near the southern margin of the mass the amount of mica greatly decreases, and the normal granite appears to pass into a border of aplite. A typical specimen of the rock examined under the microscope by MR. TEALL, is described by him as composed of oligoclase, alkali-felspar, quartz, biotite, and muscovite (scarce). The alkali-felspar shows traces of microcline-structure, and vermicular pegmatite is present. Though there is sometimes a tendency towards a parallel arrangement or orientation of the flakes of mica, the rock cannot be said to be foliated.

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District.
(Mr. Hinx-
man.)

The junction of the rock with the surrounding schists is, as is usual with the intrusive masses of the central Highlands, exceedingly complex and irregular. The granite is fringed with innumerable apophyses and detached veins traversing the schist, while fragments of the latter are thickly scattered as inclusions within and near the margin of the mass. Neither in the main body of the rock nor in its apophyses is there any appearance of a chilled edge, the rock in the smaller veins being as coarsely crystalline as in the interior of the mass. It may be further observed that the trend of the boundary of the granite, and of its fringing veins, as well as the disposition of the inclusions, has a marked tendency to conform to the strike of the surrounding schists. The inference may be deduced that the intrusion of the granite may not have been accompanied by any great disruption of the rocks, but that it rather took the form of a sill, which has made its way more or less along the planes of schistosity. The absence of any distinct foliation in the rock, even in its smallest apophyses, seems to differentiate the Glen Orrin Granite from the granites of East Sutherland, in which foliation of the margin and offshoots is a marked feature. Not improbably this mass may belong to the period of intrusion of the newer granites of Strathspey, to which it bears a considerable resemblance in character and composition.

A comparison of the Glen Orrin granite with the granite and pegmatite of Strathglass, above described, shows a striking resemblance in composition, and even in minute structure between the two rocks, the Strathglass pegmatites being slightly the more acid of the two. It seems therefore reasonable to assume that these veins of acid material may possibly be due to a later phase of the intrusion of the same magma.

DALRADIAN OR YOUNGER SCHISTS OF THE SCOTTISH HIGHLANDS.

For some years past the Geological Survey, while prosecuting the mapping simultaneously in the north-western counties and in the central, eastern, and southern Highlands, has refrained from any attempt to correlate the great series of schists of the region to the west of the line of the Great Glen with those to the east of that line. It has long been abundantly evident that in the north-eastern, central, and south-western Highlands the schists represent a great succession of truly sedimentary rocks. The age of these rocks and the date of their metamorphism remain still to be ascertained, though some progress towards the solution of these problems has already been made. But there can be no doubt that the phyllites, quartzites, grits, conglomerates, and limestones which extend from the shores of Elgin, Banff, and Aberdeen to those of Islay and Jura have had a sedimentary origin, and may yet find a definite place either among pre-Cambrian or post-Cambrian formations. The occurrence among them of igneous rocks which have shared in their metamor-

phism, and of later eruptive masses which have not been touched by the alteration, has been recognised not to affect that fundamental conclusion, even though in some places granitisation and foliation have been carried so far that it may be difficult to decide where a line should be drawn between what was originally eruptive and what was originally sedimentary material.

To the west of the line of the Great Glen, however, another kind of problem arose for consideration. In Sutherland and Ross the rocks that were found to have been pushed by vast overthrusts above the highest visible Cambrian limestones presented structures of extreme complexity, and for a time little light was obtainable as to their true succession and probable origin. Even now, after some years of careful scrutiny, it cannot be said that we have advanced far towards the removal of the difficulties with which any attempted interpretation of the ground is at once confronted. But there is a general agreement among the various officers who have been engaged in the research that the crystalline schists east of the great thrust-plane that destroys the continuity of the Cambrian succession of strata, include slices of the old or Lewisian gneiss, which have been dragged up from the east, and have been thrust westward towards the great rampart of unmoved ground which extends from Cape Wrath to Applecross. Some of these slices are of vast size. One, of which only a portion has yet been mapped, in the south of Ross-shire, must far exceed fifty square miles in area, and must be several thousand feet in thickness. These moved masses have had new structures developed in them by the mechanical deformation to which they have been subjected, but the traces of their original characters as part of the Lewisian gneiss have not been wholly effaced.

Much more difficulty has been encountered in the endeavour to trace the structure and history of the vast mass of crystalline granulitic schists, which have been grouped under the general name of "Moine-schists." Probably various groups of rock have been crushed and metamorphosed to make up these schists. As the mapping has advanced southwards, evidence has increased that much of the Moine-schists consists of material that was laid down as sediment. Probably the Torridon sandstone was largely drawn upon in the process of the manufacture of these schists, and there may also have been Cambrian or even later sediments which underwent the same conversion into a foliated crystalline condition.

The recent progress of the Survey in the Central Highlands and in Eastern Ross-shire has shown that the peculiar granulitic structure and composition of the Moine-schists, with their traces of colour-banding and even false-bedding, and their intercalated bands of muscovite-biotite gneiss, are precisely reproduced among the rocks of the Central Highlands. The two types of quartzose-flagstones and banded muscovite-biotite gneisses recur under similar conditions in Sutherland and Ross and in Inverness and Perth. The one suggests that they were originally sandstones,

grits, or arkoses, while the other may have been of a more complex and argillaceous composition.

How far this identity of petrographical character can be taken to imply geological synchronism may be matter for discussion. Without at present attempting to decide this question, we may, in the meanwhile, conveniently retain the provisional name "Dalradian" for the younger schists of the region east of the line of the Great Glen. If it shall be shown, as seems probable, that the Moine-schists of the north-west pass into and form part of the Dalradian series of the Central Highlands, a step will be gained towards the solution of the problem as to the age and origin of the schists of both regions. We know that the Moine-schists of the north-west have been pushed into their present positions, and probably have acquired their present crystalline characters since Cambrian time. The Survey has detected bands of what appear to be Arenig rocks wedged in among the schists and grits along the southern border of the Highlands. It thus seems possible that the plication and metamorphism of the Highland schists were not concluded until Lower Silurian time, and that these schists may have originally consisted partly of older Palaeozoic as well as Pre-Cambrian sediments.

Aberdeenshire.

Bynack District, Deeside.
(Mr. Barrow.)

The area surveyed last year by MR. BARROW lay around the Bynack, near the western source of the Dee. The mapping of the basin of Deeside is now complete, with the exception of a few small and rather inaccessible patches. For convenience of description the Bynack district may be divided into two parts, separated by a great fault—a continuation of the Glen Tilt fault, which has now been proved to continue far into Aberdeenshire. Not only does this line of dislocation correspond for a great distance with a marked dissimilarity in composition of the rocks on either side of it, but to a considerable extent it also coincides with a line marking a rapid decrease in their metamorphism.

The area west of the fault is composed entirely of crystalline gneisses, varying in tint from rather dark grey to nearly white, the change in tint being mainly due to the varying amount of brown mica present. By far the greater part of the series is highly quartzose, and possesses a typical mode of weathering. In the streams these rocks form massive pavements, admirably shown in the bed of the Geldie above its junction with the Dee. On the hillsides, free from drift, they form long ribs or terrace-like lines. Both in their dominant grey tint and in their mode of weathering they are substantially identical with the grey Moine-schists or gneisses of the north-west Highlands. Some subordinate bands of highly micaceous gneiss associated with them are characterised by a softer mode of weathering than the angular forms of the rest of the rocks. These bands alone contain abundant white mica; in most of the others this mineral is con-

spicuously absent. As in other similar areas, this absence of white mica is accompanied by a total absence of the lenticular or overthrust structure, so characteristic of nearly all the true schists in the southern Highlands that have resulted from the alteration of sedimentary rocks. The perfect parallelism of the bands of different coloured material in many specimens is no doubt original bedding. It strongly recalls the curious intensification of the bedding produced in many banded rocks by contact or thermometamorphism. The splitting faces are often coated with brown mica, which imparts a bronzy aspect to the rock. From the highly quartzose nature of these gneisses alumina-silicates are not common in them, although with a hand-lens minute garnets can often be made out, which possess the clear port-wine colour shown by the same mineral in the sillimanite-bearing rocks close to the Galloway granite. These little garnets are most abundant in a white rock in which the quartz-grains are embedded in a paste of white felspar. By the aid of this rock, which can be easily recognised, the great spread of gneisses is seen to result from the complicated folding and subsequent metamorphism of a comparatively thin group of strata.

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The microscopic examination of the gneisses shows that some of them possess remarkable structures. In addition to the common granular structure, from which they are usually classed as granulites, they present two others. The one which can easily be made out with a hand-lens, and may be conveniently called quartz-bleb structure, has the quartz embedded in a matrix of felspar, which often extinguishes in fairly large sheets. The other can only be made out with the aid of a microscope, and may be termed "pseudo-igneous," for structurally some of the rocks of this type are identical with many granites. They contain abundant micro-pegmatite of the vermicular type, and are specially rich in alkali-felspar, mostly potash. It may be that the original presence of the potash-felspar gave rise to these structures so characteristic of rocks that have been in a state of actual fusion. The large proportion of potash may have enabled these rocks to attain a state at least approaching pasty fusion, while the other bands in which potash is not so abundantly present were unable to do so. In the Southern Highlands, rocks possessing such igneous structures have been met with at only one other locality among the lowest known rocks in Dee-side, where again the rock is rich in potash-felspar. A striking feature of the whole area west of the great fault is the singular uniformity of the metamorphism. The rocks about Loch Tilt are just as highly crystalline as those six miles off, close to the edge of the great mass of the Cairngorm granite.

Over the entire district pegmatite occurs in two forms, either as little sills, which are of local occurrence, or as little dykes which, while never absent over any large area, tend to form a perfect network in the districts where they are specially abundant. The sills have a pronounced white colour, and are composed of *augen* of white potash-felspar, surrounded by

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trict, Dee-side.
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quartz-felspar material. With the latter muscovite, and at times garnet, are abundantly associated, and the whole rock possesses an intensely "flaser" aspect, not a vestige of which is seen in the newer granites of this region. The small dykes have a very distinct aspect. They often possess an outer margin of coarsely crystalline felspar, within which is a finer and greyer material. The grey colour of this inner material is due to the presence of brown mica. White mica and garnet are also present, but this part of the dyke is of very variable composition. These rocks possess the intense hardness of the similar dykes of the Cairnshee magma so abundant in the Banchory area, and there can be little doubt that these pegmatites represent a portion of that intrusion. The field-work of previous years has shown that the Cairnshee magma reaches the surface along a belt of ground stretching from the coast at Aberdeen, where it is specially abundant, to a point some distance above Aboyne, and its occurrence in Upper Dee-side in a direct line with the belt already referred to, serves to confirm the conclusions arrived at in the case of the muscovite-biotite-gneiss of the area to the south. Here the pegmatites of the Cairnshee type continue in a gradually narrowing belt for at least 40 miles, though the granite itself never reaches the surface. These phenomena accord with those recorded from the study of the Brittany Granites, by DR. BARROIS, who has shown that there is a long and a short axis to a series of granite intrusions. Along the long axis the granite is met with repeatedly, and even when it sinks beneath the surface its presence at no great depth is often shown by the alteration of the overlying rocks. In the direction of the short axis, the metamorphism steadily decreases as a rule, and further exposures of the granite are rarely met with. The older granites exactly reproduce these conditions in the great distances through which the granites make their presence evident by their pegmatites, and the extreme slowness with which the metamorphism decreases along these belts. In a direction at right angles to the longer axis the pegmatites usually disappear rather rapidly, and a steady decrease in metamorphism is well marked. Around the head of the western branches of the Dee the pegmatites are specially abundant along a belt stretching from a point a little west of Loch Tilt to the Chest of Dee, and running roughly parallel to the line of decreasing metamorphism. Where they disappear to the north and north-east is not yet exactly known, but to the east and south-east they rarely cross the stream flowing from the head of the Tilt to join the Dee at its junction with the Geldie. The line marking the limit of uprise of the pegmatites corresponds exactly with the line of rapid decrease to the east and south-east in the crystallisation of the schists, and thus while the highly crystalline character of these Moine-gneisses has not been induced by the newer granite, its connection with the pegmatites seems specially clear. That these pegmatites do not belong to that granite may be inferred from the fact that not only do they not increase in number towards the great intrusive

mass, but on the contrary frequently decrease, as may be clearly seen from the sections in and about the bed of the Dee. The pegmatites are specially numerous near the Chest of Dee and for some distance further up the river. They then decrease in number, and are rare near the granite. The actual junction of the Moine-gneisses and the Cairngorm granite lies in the bed of the Dee, and the marginal phenomena of the granite can be clearly studied. The hard pegmatites, if present at all, are there represented by two minute veins in the whole section.

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At the southern end of this section in the Dee the pegmatitic material that really does belong to the newer intrusions may be seen. It consists of a red friable material, of variable composition, but always rich in potash-felspar, together with quartz, garnet, and muscovite. Occasionally it is pale in colour and sometimes must be broken before it will disclose its true nature. In addition to its friability, it possesses the distinctive character that no large block is ever free from drusy cavities. On the margins of these cavities the rock is coarsely crystalline, and the minerals have some of their crystalline faces more or less well developed. It is in such cavities that the well-known "Cairngorms" occur. This drusy character, everywhere present, is seen in the veins in the granite about Loch Muick, on the margins of the Ballater mass, and on the border of the Cairngorm granite in the Invercauld Forest. In the last-named ground this material also occurs well away from the main mass of the granite, where, having no longer a high temperature environment, it consolidated in fine-grained garnet-bearing dykes. The composition of these rocks about the head of the Dee makes it evident they must be newer than the main mass of the Cairngorm granite. They frequently cut that rock. It is needless to state that the hard white pegmatites never occur within the granite. A remarkable feature of the Cairngorm mass in this district, as in others, is the fine grain of many of the intrusions within it. Indeed, when free from druses, they are mostly fine-grained. In this respect there is a remarkable contrast between the small acid intrusions in the granite and those in the diorite. Similar material, occurring even on the outer edges of the diorite, is invariably coarsely crystalline.

In the area east of the great fault above referred to, surveyed by MR. BARROW, the Moine-gneisses are abruptly truncated by the dislocation, and with one exception an entirely different set of rocks lies on the east side. The observer suddenly enters upon the domain of the well-known Highland quartzite and limestone. Between these two members of the series a lenticle of altered sedimentary rocks of very variable composition and thickness is observable. In some places, however, though rarely in Upper Deeside, the limestone lies in direct contact with the quartzite, as so often happens in the Ben-y-Glo area. The lithological variations of this intercalated lenticle forcibly remind us of those so frequent and conspicuous at the base of any of the limestones of the Yoredale

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series. As in that Carboniferous succession, there may originally have been a shale, a sandy shale, or a sandstone at the base of the Highland limestone. The mapping has shown that, on the whole, the most common material was probably a dark shale containing a small band of dark, somewhat carbonaceous limestone a foot or so thick. The intense plication which this lenticle has undergone gives the deceptive impression at first of a thick mass of strata, but it has been known for some years that the dark shale was really a thin band. The repeated folding and reduplication of the little dark limestone enables this structure to be clearly determined, as the Moine-gneisses already noticed are shown by the incessant folding of the curious white garnet-bearing rock to have acquired their apparent thickness by intense plication.

The great fault that gives to Glen Tilt the aspect of a huge furrow driven by a gigantic plough is not an isolated line of fracture. It is simply the master-fault of a great series. This series of parallel faults is crossed by a set of minor dislocations, which can rarely be traced far, though so great is their number and so potent have been the effects of their production, that in special localities it is almost impossible to find a specimen of rock not more or less decomposed by shattering. The main lines of fracture are often taken by dyke-like intrusions of newer granite material which occasionally attain the breadth of nearly a mile. The intrusive material may be entirely unaffected by the fault, all movement having ceased before consolidation; it may show a foliated or flow structure due to final movement during consolidation; or it may be actually crushed by post-consolidation movement. The last phenomenon is rarer than might be supposed, and is always confined to the margins of the dyke or special thin bands within it. Microscopic sections prove that specimens showing flow-structure and others showing post-consolidation crush may be found within a foot of one another. Indeed, all three phases may be at times met with in the same dyke at different parts of its course. That these faults are in the main older than the granite in them is obvious; it is equally clear that they are post-metamorphic; for not only do they completely destroy the crystallisation of the unbroken rocks, but, in addition, they bring the broken and decomposed material into a specially favourable condition for being acted upon by the intrusions. From an examination of thin slides made from a decomposed garnet-schist along the side of one of these faults in and about which the newer igneous intrusions were specially abundant, it appears that a new, very fine criss-cross micaceous structure has been developed, closely resembling that produced by the action of the great whin-sill in the North of England. Though a purely contact-structure, it bears no resemblance to the coarsely crystalline structure of the "hornfels" of the district; which is both cut by these faults and contains numerous intrusions of similar material. The more the evidence afforded by these dykes is examined the more clear is it, in Mr. Barrow's opinion, that the metamorphism of the whole region took place

before the uprise of the granite, any local small alteration that may occur being at the expense of this older crystallisation and of a very low type.

After leaving the upper Dee-side district, MR. BARROW and MR. CUNNINGHAM-CRAIG made an effort to finish the field-work in the district about Balmoral. This, however, they were unable to do as the ground proved to be of a more complicated nature than had been anticipated. Instead of a simple mass of normal granite, the intrusions of the age of the newer granite have proved extremely variable and complicated. They range from a distinctly basic diorite to a pale acid rock rich in potash-felspar. The latter occurs chiefly in small patches and veins on the margins of the diorite. At times the two rocks are sharply distinct; at others there is an insensible passage from one to the other.

Balmoral District. (Mr. Barrow.)

Standing on any elevated point outside the main mass of the Lochnagar Granite, this intrusion is seen to rise abruptly from the lower ground generally supposed to be composed of metamorphic rocks. Detailed mapping has now shown that close to the foot of the rising ground lies a series of patches of diorite of all sizes, which no doubt indicates the top of a large mass, more or less continuous under ground. Where these break through the metamorphic rocks the diorite is often fine in grain. The conviction from the field-work grows that fineness or coarseness of texture in such cases is largely due to the proximity to, or depth below, the original top of the mass.

The cordierite-hornfels has proved to possess a greatly wider extension than was formerly supposed. Exceptionally large masses of it occur on the north side of the Dee, about Inver. The actual tracing out of this type of alteration shows that, while often found close to the granite, it also often occurs at a distance of at least three miles from any large mass of that rock, the highly aluminous rocks that intervene being intensely foliated sillimanite gneiss.

The district of Braemar, in which MR. CUNNINGHAM-CRAIG has been engaged for several years, was revisited by him last year, and he spent rather more than three months there, partly in the western part of the Glen Ey Forest, partly further north among the Cairngorm Mountains, and partly in the Forest of Balmoral. But the necessity of completing some scattered outstanding areas in the southern Highlands required him to pass the early and the late part of the working season in the counties of Perth, Stirling, and Dumbarton. He has supplied the following notes regarding the chief results of his recent field-work in the Braemar district:—

Braemar District. (Mr. Cunningham-Craig.)

While generally confirming the work of previous years, which has been described in former *Summaries of Progress*, MR. CUNNINGHAM-CRAIG, in the course of mapping the black schist, limestone, and quartzite to the west of Glen Ey, has obtained new evidence bearing on points of special interest in the geology of the district. Among these the question of the order of succession of

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the rocks may be specially mentioned. In the *Summary* for 1897 (page 54), reference was made to indications of considerable local contemporaneous erosion and deposit between the limestone and the quartzite, and, though the order of succession was not definitely stated, attention was called to the fact that the bed of limestone nearest to the quartzite is occasionally absent, as indicated by the sections near the head of Glen Ey. The adjoining ground to the northward has now been surveyed, and the evidence, while fully bearing out what has already been stated, is much clearer and more definite. The band of limestone which appears nearest the quartzite is there, as in Glen Ey, a pure saccharoid marble, which is occasionally almost in actual contact with the marginal beds of the quartzite, while, where it is absent, the quartzite comes in contact with certain variable schists often observable between the saccharoid bed and the less pure or "ribbed" limestone beds. These schists are frequently associated or intercalated with the latter. In sections in Coire Bhourneasg the quartzite, with bands of the "Coire Neid beds," seems to transgress the bedding of the variable schists, which occasionally intervene between it and the limestone, and in one or two instances it may be seen striking obliquely at and transgressing the beds of the limestone. Further down Glen Connie the quartzite lies in contact with the black schist, the limestone not being present, though in Coire Bhourneasg it occurs in a thick folded mass between the two rocks. In the Allt an t'Sionnaich specimens of what may be described as a calcareous quartzite show the bedding and banding of the quartzite, but contain a considerable quantity of carbonate of lime; the rock may have been originally a calcareous sandstone, formed by the deposition of arenaceous material contemporaneously with the erosion of a limestone.

Observations of the "pitch" of the folding give confirmatory evidence. At the head of Coire Bhourneasg a folded mass of limestone is seen distinctly "pitching" under a belt of biotite-schist, and the latter in turn "pitches" beneath the rusty "Coire Neid beds," *i.e.*, the lower part of the quartzite, which distinctly surmounts them in this section. From these data it may be inferred that the order of succession in this district is as follows in descending order:—

1. Quartzite—Rusty and thin-bedded "Coire Neid beds" (not always present).
2. Local unconformability.
3. Variable schists (frequently absent).
4. Limestone.
5. Black schist.

The black schist, as typically developed in the district, must be distinguished from the fine biotite-schists which frequently appear above the limestone and often closely resemble the former rock. This distinction has been noted on the field-maps wherever possible, but as the limestone appears to be developed

in lenticular beds and is occasionally absent, especially where the black schist attains its greatest development, confusion between the two horizons is liable to arise.

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In this connection the fact may be recalled that the conglomeratic deposit discovered in Corriemulzie glen (*Summary of Progress* for 1897, page 53), and considered as possibly representing the "boulder bed," contains numerous subangular and rounded pebbles of the typical fine purple biotite-schist and other variegated schists which have been frequently observed between the "ribbed" limestone and the saccharoid marble band. The horizon of this conglomeratic deposit lies between the quartzite and limestone, and the bed, though never well exposed, occurs actually on the margin of the quartzite.

In the northern part of Glen Connie, and in the ground between that valley and the Dee, flaggy and granulitic biotite-gneisses form the country-rock, to the exclusion of all other deposits, with the exception of bands of quartzite, which become more frequent and more massive to the southward. In this district, and in the area of metamorphic rocks north of the Dee, surveyed during the past season, the folding is flattened, and shearing movements have been relatively severe. North of the Dee, in this series of granulitic gneisses, zones or belts, consisting wholly or in great part of quartzite, can be mapped out along the hillsides for considerable distances. No evidence of unconformability between the bands of quartzite and flaggy gneisses has been detected, and so far the evidence bears out the suggestion (*Summary* for 1898, page 24) that these rocks may be the equivalent of the granulitic gneisses and quartzite of the Banffshire series, though they differ considerably from them in lithological characters.

West of the entrance to Glen Ey a felted muscovite-biotite-schist, conspicuous on Creag a' Chait among the flaggy biotite-gneisses, resembles closely the felted schist with quartz and albite segregations, described in the *Summary* for 1897 (p. 53), as occasionally appearing between quartzite and limestone. The same rock may be seen in the Ey section, south of the Colonel's Bed, in contact with a much sheared greenish amphibole-schist, which may be a crushed epidiorite, but is more probably the impure edge of a calcareous band, sheared and affected by thermometamorphism.

The western margin of the diorite, which has now been mapped, follows the eastern side of Glen Derry, where it comes in contact with the granite, and is pierced by several minor intrusions and tongues of granitic and pegmatitic material. In the course of the season, 20 square miles of the Cairngorm granite were surveyed, but nothing of importance can be added to what has already been published (*Summary* for 1898, pp. 25 *et seq.*) with regard to that intrusion. Variations in the texture of the rock are frequent, but, as a rule, without any clearly defined boundaries. Thin quartz-reefs and crush-reefs are noticeable, especially on the high ground; zones in which these are common may be seen near the summit of Beinn Muich Dhui. The

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crush-veins have probably originated during movements in the granite mass, after its upper part had consolidated. The latest phase of the residual material, which has crystallised in cavities and in fissure-veins, caused by the contraction of the solidifying mass of granite, may be described as a muscovite-pegmatite. It is sometimes very coarse, and shows frequent graphic intergrowths of quartz and orthoclase.

About 17 square miles of the Lochnagar granite mass have also been surveyed. The rock forming this intrusion, though generally similar to the Cairngorm rock, presents many minor points of difference. It is never so coarse in grain as the main mass of the northern intrusion, and never attains on weathering such a deep red colour. Biotite is in some cases more conspicuous in it, while the rock apparently contains more oligoclase, and is, in consequence, hardly so acid in character. The residual material in veins is, as a rule, less coarsely crystalline, and also less acid in composition than in the Cairngorm mass, biotite being frequently present.

In the area west of Glen Ey, large irregular intrusions of a remarkable porphyritic rock are exposed, which can be traced to the Perthshire border. The principal intrusion attains a length of three miles, with a breadth varying from one-third to two-thirds of a mile, while other masses of lesser area, together with small dykes and sills of similar material appear in burn-sections. The largest mass stretches from the ridge north-west of Allt-an-Odhar shieling, over the top of Cairn Creagach, and along the ridge between Glen Connie and Allt Sionnaich in a north-north-easterly direction to the hill-top west of Aucherrie, and is never observed at a lower level than 1,600 ft. At several points this intrusion has vertical or highly-inclined margins, but it spreads out in a sill-like mass over the hill-tops, and is capped in one instance by a cake of metamorphic rocks. A similar but smaller mass of rock occurs on the westward side of a tributary of the Connie, at a distance of 300 yards from the main intrusion, while the same rock appears on Geal Charn on the Perthshire boundary as an extension of masses mapped in Perthshire some years ago by MR. DAKYNS. The main mass evidently acts as a somewhat irregular sill, as is shown by its mode of occurrence and form, especially the V-shape of the margin in the Allt Sionnaich glen. The material of these intrusions presents several differences from the other igneous rocks of the area. The rock is essentially porphyritic, and usually consists of phenocrysts of plagioclase, quartz, and biotite in a matrix which varies from holocrystalline to cryptocrystalline.

MR. TEALL describes one of the coarser-grained specimens (8498) as containing "idiomorphic plagioclase (oligoclase-labradorite), orthoclase (scarce), quartz, biotite (more or less replaced by chlorite), and iron ores. The rock is intermediate between a granite and a porphyrite; but rather more allied to the former than the latter." Another specimen, taken from the heart of the mass, contains a little microcline, and interstitial micropegmatite. It is thus seen that these intrusions are more

basic than the normal acid intrusions of the Braemar area, but resemble on the one hand the Glen Tromie porphyry described by Mr. HINXMAN, and on the other hand the Newbiggin dyke described by MR. BARROW. It is remarkable that, although in the centres of these intrusions the structure approaches that of a granite, the rock being holocrystalline throughout with no groundmass, in the marginal areas a groundmass is well developed, and frequently quite compact in appearance, while the phenocrysts maintain their normal size and appearance in it, with rather more distinctly idiomorphic outlines. Thus it is evident that the intrusion of these rocks has taken place when the surrounding rocks were at a comparatively low temperature and that the margins of the mass consolidated more quickly than the centre. The difference of texture is especially noticeable where the intrusions have a sill-like form, while where a vertical margin is observed, the effects of rapid cooling are not so conspicuous.

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Small dykes and irregular intrusions of the more quickly cooled variety of the granitoid porphyrite are observed in the Allt Cristie Mor and Allt Cristie Beg to the northward of the main masses, and it is remarkable that in these instances the igneous rock only appears at a comparatively low level. It is not clear how far the larger masses have been intruded along previously existing fault-lines. One of the masses upon the Perthshire border (Geal Charn) may have been so intruded, and this is also probably true of an ill-defined mass of finer and more acid material (the normal quartz-porphyry of the Braemar area), which appears on the ridge north-west of Glen Connie; but the main intrusion does not appear to follow any line of dislocation. On the contrary, the igneous rock has been crushed and shattered by fault-movements in at least two localities, viz., on the south-east side of Glen Connie and in the lower part of the section in Allt Sionnaich. MR. TEALL describes a specimen (8501) from the former locality as "a crushed igneous rock. The original rock was probably similar to those described above (8498)." The quickly-cooled edge of part of the large intrusion is described as follows by MR. TEALL: "8502, Phenocrysts of plagioclase, corroded quartz, hornblende, and biotite, in a micro- or crypto-crystalline matrix. Carbonates, chlorite, and epidote as accessories. Quartz-porphyrite."

The more acid of the lamprophyre sills and dykes—fine-grained, dark-coloured rocks, containing phenocrysts of red plagioclase, and occasionally hornblende—are frequently found in the neighbourhood of the granitoid porphyrite intrusions, but no inference of a common origin can be adduced from this association. Included in the main mass, however, on the north side of Allt Sionnaich occurs a patch of basic diorite, of which MR. TEALL supplies the following description: "Brown hornblende, augite and altered plagioclase, with apatite and iron ores as original, and carbonates and chlorite (after augite) as secondary accessories; augite-diorite." This rock is probably of earlier date than the porphyrite.

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The latest phase of these remarkable porphyritic intrusions is seen in fine quartz-porphyrries which are very noticeable near the edge of the larger masses, and which radiate out from the margins. These resemble in all respects the quartz-porphyrries of the Braemar area, having invariably a fine micro- or crypto-crystalline ground mass, containing idiomorphic phenocrysts of quartz and potash felspar. In some cases, where these late intrusions being small very quickly cooled, the rock is a fine felstone with a well-marked banding due to flow.

Taking the whole area into consideration, we have a belt of country characterised by the presence of intrusions of a composition intermediate between the lamprophyres and the acid granites and quartz-porphyrries: in some cases the intrusion may have taken place along fault-lines, but the rocks have also been considerably affected since their consolidation by the north-east to south-west fault-movements. In the northern part of the district the igneous rock has not reached to such high levels on the present surface of the ground, as in the southern part. Lastly, the latest and most acid phase of the injected material is indistinguishable from the Braemar quartz-porphyrries, while the larger masses of the intermediate rock appear to be of more recent date than the diorites and some of the lamprophyres. From these facts MR. CUNNINGHAM-CRAIG infers that he is dealing here with a phase of the newer granite magma, intruded at a locally intermediate stage in the differentiation, which has given rise to basic diorite and lamprophyres, highly acid granites and quartz-porphyrries in contiguous areas. The intrusion has taken place while the surrounding rocks were at a comparatively low temperature, as evinced by the fine-grained chilled margins. The source of the igneous material may be looked for in an underlying magma, the existence of which has been previously suggested by the evidence in neighbouring areas. As the latest of the granitoid porphyrite intrusions have been shown to resemble closely the quartz-porphyrries associated with the Auchindryne granite, it may be assumed that the latter intrusions are somewhat later in date than the granitoid porphyrites—an assumption borne out by the fact that the Auchindryne granite and its apophyses have been intruded since the north-east to south-west fault-movements, while the granitoid porphyrites have been more or less affected by these movements. The distinctly less acid composition of these remarkable intrusions also favours this suggestion.

Specially interesting evidence bearing on the question of thermometamorphism has been met with in the tract west of Glen Ey, from which the rocks can be traced continuously eastward into an area of greater metamorphism, while outcrops of black-schist, limestone, and other deposits capable of showing clearly the effects of alteration occupy a large part of the surface, and can be examined to great advantage both in burn- and hill-sections. Kyanite is commonly observed in the black-schist, and staurolite more rarely; but the crystals, which have been developed since all shearing movement ceased, are

not so large and conspicuous as those seen in Corriemulzie Glen. The tremolite-rock and the garnetiferous sill of horn-blende-schist are well seen, though the former is never so highly crystalline as in the metamorphic area east of Glen Ey.

Braemar district. (Mr. Cunningham-Craig.)

But the most interesting feature is the entire absence of the production of hornfels, except at the contact with igneous intrusions; it is evident that in Glen Connie we are beyond the hornfels area, and have entered a belt of country in which the metamorphism has not attained to that relatively intense degree of alteration. The limestones appear very little affected, except where in contact with the granitoid porphyrite intrusions. The metamorphic effects of these intrusions are of greater interest. It has been pointed out that though these igneous masses attain to considerable dimensions, they have quickly cooled margins, so it cannot be expected that any very extreme type of metamorphism should be observed in the sedimentary rocks along the lines of contact. A certain amount of alteration, however, has undoubtedly taken place. Where the granitoid porphyrite comes in contact with impure limestone bands in Allt Sionnach, the latter are converted into a compact banded hornfels. MR. TEALL describes a specimen (8503) as follows:—

“Compact banded hornfels.—The specimen contains a band of dark-purplish hornfels between bands of grey and pale green hornfels. The dark purplish hornfels owes its colour to the presence of minute scales of biotite. The other constituents are granules of pyroxene and a colourless mineral, the grains of which are too small for precise identification. They are probably either quartz or felspar. The grey bands are devoid of biotite but richer in pyroxene. They also contain grains of the colourless mineral and large individuals of a mineral belonging to the scapolite group (dipyre). The scapolites are crowded with inclusions of pyroxene in the form of minute grains. The grains in the scapolite are distributed in exactly the same manner as in the rest of the rock, so that the outlines of the crystals can only be distinguished in polarized light. Similar rocks have been described from the Pyrenees as ‘cornéennes compactes’ by Professor Lacroix. They are there regarded as Lias altered by contact with lherzolite.”*

Purer bands of limestone, in Glen Connie, are found near the igneous rock as white saccharoid marble, with traces of calc-silicates, which have not been determined.

No contact between the true black schist and the porphyrite is exposed in this area, as the intrusions are for the most part confined to the neighbourhood of the limestone, but a thin fold of black schist seen in Allt Cristie Mor among minor intrusions of the granitoid porphyrite, has been converted into an andalusite-hornfels, which MR. TEALL describes as “(8506) Micaceous aggregates with cores of unaltered andalusite, quartz, and biotite. Andalusite-hornfels (altered).”

* Etude Minéralogique de la lherzolite des Pyrénées et de ses phénomènes de contact. *Nouvelles archives du Muséum d'Histoire Naturelle*, 3rd ser., pp. 209-302.

Braemar
district. (Mr.
Cunningham-
Craig.)

The "purple schist," so frequently seen associated with the banded limestones, is also much affected near the junction with the intrusive rocks. It is essentially a quartz-biotite rock, but by the development of minute plates of "contact" biotite, it has been converted into a hard biotite-hornfels, the bedding being completely obliterated. Two specimens of the rock from different localities are thus described by Mr. TEALL: "(8504) Black compact rock showing junction with porphyrite. It is composed of numerous quartz-grains in a matrix containing small scales of biotite and minute opaque dusty particles (? carbonaceous). The rock has the structure of fine grit."

"(8505) Very fine grained, almost compact, purplish hornfels. Minute scales of biotite and some larger crystals of white mica in a colourless mosaic, largely, if not entirely composed of quartz. Biotite-hornfels." The zone of alteration round these porphyrite intrusions is narrow, and little trace of the alteration can be detected in hand-specimens taken at a distance of a hundred yards from the igneous rock; the specimens examined microscopically were all taken from within 100 feet of the porphyrite, some from the actual junction.

Perthshire and Stirlingshire.

District
between Brig
o' Tuire and
Loch
Lomond.
(Mr. Cun-
ningham-
Craig.)

In continuation of his previous survey in these counties for the completion of Sheet 38 of the one-inch map of Scotland, Mr. CUNNINGHAM-CRAIG has mapped the "Green-beds" in the neighbourhood of Brig o' Tuire, and from that ground south-westward in a zone reaching through Loch Katrine and Loch Chon into Rowardennan on the eastern shore of Loch Lomond. As stated in last *Summary of Progress*, the mapping of these epidiotic grits, by affording a reliable horizon, has sufficed to explain the nature of the folding, and to make clear many points in the structure of the district, which could not previously have been detected.

North of Brig o' Tuire in Glen nam Meann and Glen Finglas the "Green beds" are found in simple outcrops resting upon the coarse pebbly grits of Ben Ledi, and dipping beneath the massive grits and schists, which at a higher level contain the main intrusion of epidiorite. Nearer to the mouth of Glen Finglas, what might be described as "corrugated outliers" of the epidiotic grits, are seen upon the hill-tops. In these outliers the folding is distinctly shown; the plication, though it may be described as isoclinal, is in no sense comparable to the deep isoclinal folding of the central Highlands, the limbs of the folds being nowhere of any depth. Thus, in these outliers, the actual folding has no appreciable effect upon the form of the outlier.

As these rocks are followed south-westward, they appear on the high ground of Beinn Aan in shallow synclinal folds which rapidly become deeper, till on the shores of Loch Katrine the rocks are "packed" into a vertical isocline. The folding in this part determines the form of each outcrop. It is observable,

however, that the folds are, as a rule, shallow and undulating upon the hill-tops, while in the lower ground the "limbs" of the folds become longer, so that the pitch of the folding—*i.e.*, the actual dip of the folded beds—is often difficult to distinguish. This structure is again complicated by a cleavage observable in the fine-grained and more homogeneous beds, but which does not greatly affect the coarser grits. In the vertical limbs of folds, this cleavage coincides with the bedding, but where the folding is shallower, the bedding crosses the cleavage obliquely, and the former structure is frequently almost obliterated, so that a false appearance of isoclinal folding is given.

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Observations of the "pitch of the folding" have been made where possible, and from these it appears that the pitch undulates considerably; this has a marked effect upon the outcrops of the "Green beds" between Loch Katrine and Loch Lomond. The effects of the rolling "pitch" are especially well seen about Loch Chon, the axes of the folds sloping towards the loch from both north-east and south-west, so that four or five synclinal outcrops appear on the shores of the loch, while the folds pinch out towards the hill-tops, and an outlier on the watershed is sometimes the only representative of a particular outcrop.

The effect of the isoclinal folding is to repeat the outcrop of the "Green beds" seven times on the southern shore of Loch Katrine. The compound synclinal folds in which these outcrops lie may be regarded as the westward extension of the trough which has been mapped from Balquhiddy and Strathyre. Each outcrop is essentially a folded syncline. On the south-east side, the great trough is flanked by an anticlinal axis of the coarse pebbly grits of Ben Ledi, packed together in a vertical isocline, that seems to have acted during the folding movement as a line of resistance, against which the folding of the less massive beds took place. The pebbly grits make their appearance here and there in minor anticlines between the outcrops of the "Green beds," and their occurrence in this manner is confirmatory evidence of the fact that in this area there is only one series of epidotic grits, which is continually repeated by folding. The small thickness of the rocks, relative to the area of ground which they cover, is also strikingly shown.

To the north-west of the trough containing the "Green beds," the folding becomes shallow and irregular, the beds being rather "puckered" than folded, and the metamorphism is of a different type. Shearing has had greater effect, and the gritty beds appear chiefly as micaceous schists, with less trace of their elastic origin. This may be partly due to an original difference in lithological character, the coarser grits attaining their maximum development to the south-east of the trough, and the sediment becoming finer in grain to the north-west. But the chief determining reason is, doubtless, the change in the character of the folding, which has led to a different degree of dynamic metamorphism. Where the folding is shallow and irregular, differential movement under horizontal stress may be expected to take place more easily, and the greater dynamic metamor-

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phism would result in the total or partial obliteration of original structures. These phenomena hold good as far as the great trough can be followed. Tracing it into Stirlingshire, the trough is seen to be affected by faults, and to become shallower towards the south-west; the outcrops of "Green beds" become fewer in number, and the folding less regular and less deep, till, near Rowardennan, at a distance of about a mile from Loch Lomond, a fault cuts off the "Green beds" entirely, the upthrow being on the western side of the dislocation.

Dumbartonshire.

The portion of Dumbartonshire between Loch Lomond and Loch Long has been searched unsuccessfully for outliers of the "Green beds"; it seems that their horizon is never actually reached, the ground being occupied by rocks of a lower horizon folded into shallow and irregular undulations, and showing no trace of the great synclinal trough.

The Luss Slates.—Boundary lines for these deposits had not previously been mapped. In tracing the outcrops, it was found necessary to map in detail certain characteristic bands of grit. The grit of Meall Garbh in the Pass of Leny, and that which makes such a remarkable feature at Anie near the foot of Loch Lubnaig, have been found to afford admirable horizons for mapping. The data obtained by the detailed survey of these grit bands has made the structure of the district clear; numerous faults have been detected, and their effects have been shown, while the somewhat irregular arrangement of the rocky islands near Luss has been explained by the presence of roughly north and south faults concealed by the lake-basin, but the existence of which can be demonstrated.

The slate-bands have been quarried for roofing material at Luss for upwards of two hundred years, but the profitable beds have now been exhausted in the present quarries. Fresh openings in the neighbourhood have failed to find workable slate in sufficient quantity. MR. CUNNINGHAM-CRAIG'S examination of the ground soon disclosed the reason for this failure. He found that a north and south fault cuts off the workable slate, bringing against it a mass of fine and coarse cleaved grits with some softer slaty beds. The general similarity of these gritty beds to the true slates deceived the quarrymen, who continued working further into the mass of grits in the hope of winning workable slate.

The fault, which splits into several branches among the finer beds, has been traced for upwards of a mile. It shifts the outcrop of the slate-band—the same band that is being worked at Aberfoyle—a quarter of a mile to the southward. Veins of quartz and calcite with some chlorite are common in the neighbourhood of this fault and its branches, frequently rendering the slate unworkable.

Inverness-shire.

In the district of Strath Nairn Mr. HORNE continued the mapping of the schists, and found them divisible into two well-marked groups: (1) Flaggy, quartzose biotite-gneiss of the Moine type; and (2) Extremely coarse biotite-gneiss, with highly-contorted folia, containing quartzo-felspathic materials, arranged in parallel folia or lenticles. With the latter are associated bands of garnetiferous hornblende rock.

In the district which includes both sides of the southern end of the Great Glen, Mr. GRANT WILSON continued the survey described in last *Summary*. He has now completed the mapping of Glen Loy. The schists which occupy the greater part of that valley are of the ordinary Moine-schist type or gneissose flagstones with quartose bands more or less felspathic and micaceous. The boundary of the diorite, part of which has been already described,* has now been traced all round. The mass, which is found to occupy an irregular area of about five square miles, appears to have been intruded more or less along the foliation-planes of the flagstones, for its eastern margin conforms closely to the changes in the direction of the foliation of these rocks. Half a mile to the west of Inverskavulin, on the banks of the Loy, where a good contact junction of this rock is seen, the granulitic flags next the diorite are much baked and shattered, while the igneous rock in close contact with them has a close-grained or chilled edge. A specimen from this place is thus described by MR. TEALL:—

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"[8489.] Coarse-grained, massive rock. Under the microscope, plagioclase (Andesine-labradorite) biotite and garnet, with apatite and iron ores as accessories. A diorite-rock in which biotite takes the place of hornblende: garnetiferous biotite-diorite."

Few granite dykes† like these mentioned in last year's report seem to cut that portion of the diorite which lies to the north of the river Loy.

On the east side of the Great Glen, or Glen Albyn, the work of last year was continued by MR. GRANT WILSON up both sides of the Spean valley as far as Roy Bridge; round the western slopes of Ben Nevis to the limit of the driving road in Glen Nevis and the greater part of the Mamore Forest.

The most important section in this area is that laid open by the River Spean from the falls of Mucomir to the junction of the River Roy, the bed and the rocky ravine of the stream affording an almost continuous exposure of the zones of schist between the rivers Spean and Lochy described in last *Summary*.‡

(1.) Sericitic mica-schist. At the falls of Mucomir a crushed and contorted green schist, slightly calcareous in places, with a few quartzite bands, is cut by several small epidiorite-sills. In

* *Summary of Progress* for 1898, p. 42.

† *Op. cit.*, p. 43.

‡ *Op. cit.*, p. 44.

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the road deviation at the Free Church Manse epidiorite-sills compose over two-thirds of the section, and to the east of the Manse, both in the river and in the railway-cutting, the green contorted schists are pierced by a large mass of gabbro, which in turn is cut by a porphyrite-dyke. On the railway below the cross-roads at Torr an Eas the rock, which is well exposed, consists mainly of dark grey and green schists with thin bands of quartzite, and a few small sills of foliated epidiorite constantly repeated by being thrown into folds. In the next railway cutting further east thin brown bands are interlaminated with green and grey schists, which appear to have been originally impure limestones.

(2.) The same narrow belt of black schist traced in 1898 by the Ben Nevis Distillery to Auchindaull, a distance of four miles, is not seen further to the north-east, and is not represented in the Spean section.

(3.) Below Coneachan dark grey flaggy micaceous schists with quartzite bands succeed the sericite-schists just described. They are isoclinally folded to east-south-east at an average angle of 50° , the same bands being frequently repeated. The epidiorite sills and dykes so characteristic of the sericite-schists still continue in this zone, though less abundantly. About 100 yards to the north of the High Bridge and in the railway-section, steel-grey flaggy schists are seen to include thin zoisite-schist partings a few inches thick. A specimen from one of these bands submitted to MR. TEALL is thus reported on by him:—

"[8559.] Hornblende and garnet in a white saccharoidal matrix. Under the microscope both hornblende and garnet are micro-poikilitic. The white matrix is a granulitic aggregate of quartz, felspar, and zoisite: hornblende-zoisite-granulite (garnetiferous)."

From this point to Spean Bridge the river section presents an alternating series of grey micaceous flags with flaky and quartzose bands. To the west of the railway viaduct the constant repetition of this series by folding on a large scale is well seen in the rocky gorge of the stream. The same group of rocks continues for a mile above Spean Bridge, either with their foliation planes on end or highly inclined to the east.

From Tirandrish for 600 yards up to the railway viaduct fine phyllites and flaky schists alternate with thin quartzose bands. Above the bridge a belt, 140 yards broad, of strong pink spotted and white quartzite with micaceous partings makes its appearance. Its relationship to the rocks on either side of it, though at present obscure, will in all probability be explained by the future mapping of the ground to the north. This quartzite is succeeded to the east first by soft grey phyllites with calcareous bands; next by a narrow belt of corrugated black schist with garnets, followed by a strip (75 yards broad) of blue crystalline limestone, with a few partings of black schist and phyllite.

To the east of this limestone, phyllites and black schist, identical in every respect with those on its west side, are repeated by numerous folds to within 280 yards of the Cour water when

solid grey and slaty limestone with actinolite extends for a breadth of 166 yards. This belt of limestone is succeeded by calcareous phyllites which can be traced to about 150 yards beyond the mouth of the Cour water.

The general strike of the foliation of the whole of this calcareous series is north-east and south-west, and the planes are either vertical or else inclined to the south-east at a high angle. The detailed mapping clearly proves that the same limestone band, with black schist on either side of it, is twice repeated, and that between these belts of limestone, and on their east and west sides, a series of similar grey phyllites and schist with calcareous bands, evidently indicates a repetition of the same zone. This calcareous series comprises the (4) limestone and (5) black schist zones, already described as extending from Lismore to Glen Nevis.*

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The calcareous series is last seen at the foot of the Cour water; thence to the River Roy it is succeeded by silvery-grey phyllites and mica-schists, often garnetiferous. A specimen from Achnafraschoille, microscopically examined by MR. TEALL, is described by him as follows:—

"[8560.] Both biotite and garnet are micro-poikilitic. The former occurs in large irregular plates, which are not arranged parallel with the schistosity. The matrix is composed of quartz and white mica with small grains and crystals of iron-ore—garnet-biotite-phyllite."

These schists, although lighter in colour, appear to be the representatives of the (2) dark-grey, flaggy mica-schists on the west side of the limestone and black schist. This identification is confirmed by the interlamination, both at Croft Ninner on the Spean and at Auchaderry on the Roy, of bands of zoisite-schist similar in every respect to those already described as occurring near the High Bridge. In close proximity to the zoisite-schist in the River Roy several belts of grey phyllite appear, which contain large feathery crystals of hornblende, occasionally seven inches long, and covered with crystals of a pale rose-pink garnet not yet determined.

A large number of broad dykes traverse the calcareous series in the Spean section. Some of these exceed 20 feet in width and all have fine-grained chilled edges. MR. TEALL has examined several of these, and finds that they belong to the lamprophyre group, and may be described as dioritic lamprophyres. On both sides of the Spean limestone, similar dykes cut the mica-schists of Glen Roy and Glen Spean, with a general trend of E. 30°—40° N. On the west side of Glen Nevis a similar group of dykes traverses the same series of strata (black schist and limestone) on Bidean Bad na h' Iolair† to the south-east of Fort William.

In the burn section between Lochan Meall ant' Suidhe and the river Lochay the Ben Nevis granite is cut by a few aplite

* *Summary of Progress* for 1898, p. 45.

† *Op. cit.*, p. 48.

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and lamprophyre dykes. In Glen Nevis and around Poll Dubh the biotite-schist, which lies to the south of Ben Nevis, is intersected by numerous lamprophyre dykes. Further north the binary granite of Mullach Nan Coirean is cut by a series of similar dykes. Their direction is the same as that of those by the biotite-schist, and many were observed to have chilled edges. A specimen of one of them from the Choire Deirg is thus described by MR. TEALL:—

“[8488.] Under the microscope it shows prismatic hornblende in a matrix of plagioclase more or less lath-shaped.—Camptonite.”

This granite area is also intersected by several coarser dykes, which in all probability are closely allied to the camptonites. A specimen of one of these from the falls at Poll Dubh, submitted to MR. TEALL, is thus described by him:—

“[8563.] Medium to fine-grained pinkish rock containing hornblende. Under the microscope hornblende, biotite (mostly altered to chlorite) in a matrix mainly composed of idiomorphic plagioclase; a little interstitial quartz—Lamprophyre.

On the Moor of Rannoch, where a small tract has been mapped by MR. WILSON, between the head of the Tulla Water and the River Ghair, a fine-grained biotite-granite has been found in place between Loch Laidon and the viaduct of the West Highland Railway. Traced to the south over the moor, this rock becomes more hornblendic and less micaceous till about half a mile from its edge it becomes a typical diorite. Several large lamprophyre dykes cut both the granite and diorite while the surrounding flagstones are intersected by diorite dykes.

Argyllshire.

District
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Kynaston.)

During the past year MR. HERBERT KYNASTON continued the mapping of the Dalradian schists in the neighbourhood of Dalmally and Inveraray. From Dalmally the work, begun some years ago by MR. J. B. HILL, was carried on up to the eastern margin of Sheet 45 (one inch), and the boundary lines of the different series were joined up with their corresponding lines along the western margin of Sheet 46. In a northerly direction the work was pushed forward to the high ground at the head of Glen Strae, whence it was carried on during July to the north-east corner of Sheet 45 from Clais-gobhair in the Black Mount deer-forest. To the south of Dalmally the mapping was continued from Inveraray during September and October in the area drained by Glen Shira. The following notes of his field-work have been furnished by MR. KYNASTON:—

The sediments mapped consist of part of the garnet-schists, the Ardrishaig series, or calc-sericites, and the black slates, limestones, grits, and quartzites of the Loch Awe series. On the east side of Glen Shira a considerable tract is occupied by the calc-sericite series, which towards Ben Bhuidhe are thrown into numerous small folds and plications with accompanying litho-

logical changes. The beds become harder and stand out in bold crags and ridges, while on the main ridge of Ben Bhuidhe itself the rock has evidently been converted into a true hornfels. Two or three small patches of granite appear on the Ben Bhuidhe range, resembling the finer-grained type of Glen Fyne; but the visible exposures of granitic rock seem too small to have caused the amount of alteration observed in the surrounding sediments. Since, however, this alteration is of a local character, and identical with the contact-type of hornfels-alteration in other areas, it would appear to be due in great part to a larger extension beneath the surface of the Ben Bhuidhe granite. It is possible that a considerable mass of granite may exist here, only small portions of which have as yet been tapped.

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To the north of Glen Shira, in the neighbourhood of Ben Bhreac, Ben Bhoidheach, and Ben Bhalgairean, the calc-sericite group has a fairly uniform lithological character, consisting of hard, often intensely puckered, greenish and grey phyllites, in which occasionally calcareous and quartzose zones may be observed. These Ardrishaig schists have here a decidedly more metamorphosed appearance (of the regional type) than further west. This fact and all MR. KYNASTON'S observations during the course of the mapping fully confirm MR. HILL'S view on the progressive metamorphism of these sediments.* From this area the Ardrishaig schists can be traced in a highly altered state to the west of Meall nan Tighearn, whence they curve round into Sheet 46 along the northern flanks of Ben Laoigh. Typical calc-sericites—greyish and greenish sericitic phyllites with numerous calcareous zones—are found at Ciochan Ben Laoigh, where they form a fine feature, and in the crags of Fìreach na Moine.

To the east of the calc-sericites come the garnet-schists. As the latter are entered the calc-sericites become gradually less calcareous as well as more siliceous and highly micaceous, until they are succeeded by massive and flaggy quartzose mica-schists, thickly studded with garnets.

On the west side of Glen Shira the boundary-line between the calc-sericites and the Loch Awe series was followed in a general north-north-east direction as far as Bealach nan Cabrach, whence it turns westward and was traced to the shore of Loch Awe close to Inistrynich. The Loch Awe series between Glen Shira and Loch Awe maintains similar features to those described in former Reports. The black schists (belonging to this series) were again met with east of Dalmally and were followed as a comparatively narrow zone along the south side of Glen Lochy to the margin of Sheet 45. In this more altered area they have the appearance of black phyllites with micaceous partings and often with quartzose bands. They are also frequently garnetiferous.

To the north of the Strath of Orehy and Glen Lochy the black schists and limestones become restricted to insignificant zones until they gradually die out altogether, and a large area is then

* *Quart. Journ. Geol. Soc.*, vol. lv. (1899), p. 470.

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occupied by quartzose schists and quartzites. The evidence of increased regional metamorphism is here again striking and apparently comes in somewhat suddenly. In fact, a considerably greater degree of metamorphism is observed in tracing the rocks for four miles from Dalnally in a north-easterly direction than in the course of the succeeding ten miles along the same line. The increase in this direction after the first four or five miles is comparatively slight as far as observations have yet gone. Near the southern boundary of the quartzose series rocks which appear quite gritty, and in which the individual grains can be easily distinguished by the naked eye, may be frequently observed, but further to the north-east the gritty nature of the rocks becomes gradually obliterated, the schistose structure grows more and more marked, until a quartzose schist is reached, which is often flaggy and maintains a uniform character over a large area, and in which the original clastic structure is almost, if not completely, lost.

Well within the altered area highly micaceous schists, often with both black and white micas and frequently garnetiferous, are not uncommon. Thus, garnetiferous mica-schists are well developed in Glen Orchy at Catinnis Bridge, and they again form a strong band near Clais-gobhair in the Black Mount, and are well seen on the south-eastern slopes of Ben Sroine. Lithologically they often bear a strong resemblance to the garnet-schists below the Calc-sericite group about Ben Laoigh and in the Glen Fyne area, but here they occur well within the quartzite area and are succeeded both above and below by quartzites and quartzose schists. The following section, observed near Clais-gobhair, may help to illustrate the relations of these garnetiferous schists. In apparently ascending order the subdivisions are:—

- (1.) The quartzites and quartzose schists, in the immediate neighbourhood of Clais-gobhair. Then, in a burn section of rather more than a mile in length,
- (2.) A green hornblendic schist or gneiss, the nature of which is at present doubtful.
- (3.) Dark grey biotite-gneiss,—the biotite often developed in elongated leaf-shaped patches, irregularly distributed on the foliation planes,—passing into a schist with two micas, often gneissose, and with some small pegmatite veins.
- (4.) Garnetiferous mica-schist, with two micas, garnets numerous.
- (5.) Pale grey flaggy quartzites,—a narrow zone.
- (6.) Silvery grey mica-schists, with two micas, only occasionally with small garnets. These rocks become very quartzose, and show, also, eyes and bands of quartzose material, which does not apparently represent extravasated quartz, but rather puckered and drawn out bands of recrystallised coarse grit. These rocks are again well seen about the east end of Loch Dochart. Near the top of this zone fine quartzite bands become more frequent and pass into

- (7.) The series of flaggy quartzites and quartzose schists, which spread over a large area.

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The green hornblendic schist (2) is a peculiar rock, regarding the nature of which a definite opinion cannot at present be given. Parts of it recall the epidiorite sills, so numerous in the Loch Awe area, but it does not seem to behave like one of these in the field. It appears to consist of a complex containing hornblendic, epidotic, and pyroxenic gneisses, sometimes with sphene, while some portions are calcareous. MR. GRANT WILSON, who mapped a portion of this schist, compared it to the scapolite gneiss, though it does not contain scapolite. Both this rock and the succeeding biotite-gneiss frequently contain small pegmatite veins. The biotite-gneiss is seen under the microscope [slide No. 8618] to be fine-grained in texture, and to consist mainly of biotite and quartz, with a small proportion of felspar, and occasionally eyes of granular quartz and small garnets. The garnet-schist [8619] is considerably coarser, but intensely puckered and well foliated. It is very quartzose and contains both white and brown micas, the former being slightly in excess, and a certain amount of felspar. The garnets have been broken up and show but little of their original substance, being now mainly represented by chloritic alteration products, biotite flakes, and granular quartz.

Almost throughout the whole area of the quartzite series surveyed, from the Strath of Orchy to the Black Mount, small pegmatite veins are fairly common. On both sides of Glen Strae and in the tract between that glen and Glen Orchy they are numerous in the quartzose schists, especially noticeable in the neighbourhood of faults. They occur chiefly as small veins and strings of coarse red felspar, usually associated with quartz, along the joint planes and other lines of weakness in the schists. Some veins consist mainly of quartz. Besides these veins, isolated pockets and grains of feldspathic material, already noticed by MR. HILL,* are well seen on the west side of Glen Strae, grains and patches of red felspar frequently occurring to such an extent as to give the rocks as a whole a reddish appearance. This MR. HILL has attributed to the presence of the Ben Cruachan Granite; that is to say, either the feldspathic material has been derived from the granite, or it represents an original constituent of the quartz-schist recrystallised owing to direct contact-action. There can be no doubt that "granitisation" of this kind has taken place in many parts of the Highlands. In the region around Ben Cruachan, however, MR. KYNASTON'S work in the field and with the microscope has led him to doubt whether the evidence might not be better explained in another way. As a general rule, as far as his experience of the Cruachan granite has gone, secondary felspar, which can be shown to be due to the direct contact-action of the igneous mass, is only found in the immediate neighbourhood of the

* *Op. cit.*, pp. 485, 486.

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actual contact, *i.e.*, in the inner zone of hornfels alteration and such secondary felspar will usually present a fresh appearance under the microscope. The fact of the quartzites having a reddish colour, due to the disseminated feldspathic grains, cannot be taken as any guide to the origin of such felspar. The majority of these quartzites and quartzose schists, throughout the ground surveyed, are rich in original felspar grains. They were at first fine-grained quartz-felspar grits, and they have frequently been observed to assume a reddish colour, due presumably to the weathering of the contained felspar, at distances from the granite very much greater than Glen Strac, and especially in the neighbourhood of faults or lines of crush, where the rocks are much shattered and decomposed. On the other hand, grey quartzose schists, containing abundant clastic felspar, may often be observed close against the margin of the granite, without any accompanying change of colour. Again, isolated grains or crystals of felspar, similar to those seen on the west side of Glen Strac, may be observed, up to quarter of an inch in diameter, in the quartzose-schists of Ben Donachan, three miles and a-half from the nearest exposure of granite, while veins and pockets of red felspar, up to three or four inches in breadth, are common in Glen Orchy in the neighbourhood of Catinnis, more than five miles from the granite. These felspar grains have always a very turbid appearance under the microscope, and are usually corroded, and often broken, and they are not restricted, as we have seen, to the zone of hornfels around the granite, but may be found several miles away from it. It is not always easy to draw the line between veins, pockets, small patches, and apparently isolated grains of feldspathic material. A similar reddish colour might easily prevail in both secondary and original felspar; but there is no doubt that the rocks here considered are highly feldspathic quartz-schists, which contain a large proportion of unquestionably original felspar, and these schists are traversed by feldspathic veins, and structures of a similar nature. These structures cannot be referred to direct contact-action, nor can they have been injected from the granite. According to MR. KYNASTON, they belong to the same set of phenomena as ordinary quartz-veins, which form a common feature in the district. Veins and pockets precisely similar to those in the quartzose schists are found in the granite itself, especially in the coarse Black Mount type. From these considerations, MR. KYNASTON would refer this vein felspar and the occurrence of secondary felspar of a similar nature, though not necessarily in the form of a true vein, not to the presence of the granite, but to the same causes which give rise to the normal quartz and pegmatite veins, so common in igneous rocks and highly metamorphic regions, such as we are dealing with. Isolated reddish grains he would regard as original clastic material. That these should have escaped obliteration from the forces which produced the schistosity of the rocks, is not, perhaps, so surprising in view of the resisting nature of the rock, and the fact that the porphyritic felspars of the epidiorite-sills are

frequently well preserved even in an area of garnetiferous mica-schists.

The sills of epidiorites and hornblendic schist are already well known from previous Reports, and those mapped during the past year do not call for any special notice. It may be remarked, however, that as the mapping advances into the more highly metamorphosed area, to the north and east of Dalmally, sills, which would be designated epidiorites and chloritic schists further to the south, have now become recrystallised, and are true hornblende-schists and hornblende-gneisses, in which the hornblende is usually dark and fresh, and biotite is frequently present, with occasional garnets. Porphyritic felspars are often well preserved and conspicuous, as in some of the sills on the Glen Lochy side of Ben Sroine. Where sills are large they sometimes vary from a fine-grained hornblende-gneiss to a fairly coarse hornblende-rock showing scarcely any traces of foliation. These sills, however, are not nearly so common in the more altered area as in the district about Loch Awe.

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INTRUSIVE ROCKS LATER THAN THE FOLIATION OF THE ARGYLLSHIRE SCHISTS.

Various large masses of granite and innumerable sills and dykes of basic as well as acid material have invaded the schists of the south-western Highlands since the time of the production of the foliation. The question of the age of these intrusions is one of considerable difficulty. They not improbably belong to different periods of hypogene activity. Some of them no doubt belong to the time of great volcanic activity when the lavas of the Lower Old Red Sandstone of Lorne were poured forth. In the *Summary of Progress* for 1897 and also in that for 1898 reasons were given to show that the granite of Ben Cruachan not impossibly belonged to that volcanic period. No new evidence has been met with to impugn or to confirm this suggestion. On the present occasion it will be more convenient to discuss the occurrence of these eruptive rocks apart from the consideration of their geological date. They have recently been studied afresh both by MR. HILL and MR. KYNASTON, and the observations of these two geologists will here be given in connection with their notes on the schists through which the intrusive rocks have been erupted.

At the time of MR. J. B. HILL's transference from Scotland to Cornwall, a large tract between Inveraray and Dalmally, on which he had been engaged was not finished. The completion of this area as well as the northerly extension of the work from Dalmally was assigned to MR. KYNASTON. As the different sedimentary series of the Loch Awe region often shade into one another imperceptibly, a more or less arbitrary divisional line had to be adopted, and in order to secure that these lines should be drawn uniformly on the same horizon, it was desirable that both surveyors should visit the ground in company so as to run

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the boundary-lines continuously from the one part of the district into the other. MR. HILL was accordingly instructed to join his colleague for a short time for this purpose, and they conjointly completed the joining up of their boundary-lines along the limits of their respective areas—a total length of 40 miles. MR. HILL took advantage of the opportunity to revisit the mountainous country between Glenfyne and the Shira River for the re-examination of the igneous rocks of Beinn Bhuidhe, and, as this work would probably have a bearing on the future survey of the ground to the northwards, he was accompanied by MR. KYNASTON.

The following description of the interesting and peculiar eruptive rocks of this district is supplied by MR. HILL. It is inserted here for convenience, but the age of the rocks must be much later than that of the Dalradian sediments which they traverse. MR. KYNASTON is of opinion that the Ben Cruachan granite not improbably belongs to the Lower Old Red Sandstone volcanic series of Lorne; while MR. HILL is disposed to regard it as of greater antiquity.

The occurrence of olivine-monzonite—a rock new to Britain—has been reported by MR. HILL in previous years from various parts of Argyllshire. He first mapped rocks of this kind in 1892 among the igneous masses forming the Beinn Buidhe complex, and apparently related to the great granite mass of Glenfyne. The following year he met with a rock identical in character on the western side of Loch Awe, close to the village of Kilchrenan. In 1896 he mapped a similar mass near Loch Avich about nine miles south-west of Kilchrenan, and described it briefly in the *Annual Report* for that year.* In the same *Report* a fuller account was given of a similar rock which MR. GRANT WILSON had mapped in the neighbourhood of Ballachulish.† During the past season MR. R. G. SYMES has met with another monzonite dyke in the Kilmelfort district (*postea*, p. 64), near MR. HILL's mass at Loch Avich, while MR. KYNASTON has mapped an example in Glenorchy. Doubtless other instances of them may be found as the mapping of the South-Western Highlands advances. With the exception of those in the Beinn Bhuidhe area, the mode of occurrence of these rocks is too isolated to throw much light on their origin. At Beinn Bhuidhe, however, an assemblage of igneous rocks can be studied which merge into one another, and among which a definite relationship can be observed both in the field and by microscopic investigation.

The extensive granite masses of Glenfyne and Ben Cruachan are separated by a space of nine miles. In the intervening ground small bosses of granite, diorite, and olivine-monzonite appear, besides sills and dykes of orthophyres, porphyrites, and lamprophyres. The granite masses of Glenfyne and Ben Cruachan are similar in character, while the occurrence of smaller bosses of granite and diorite between them may indicate an underground

* *Annual Report of the Geological Survey for 1896*, p. 23

† *Op. cit.*, p. 21.

connection between them—a connection further indicated by the enormous amount of the hornfels type of alteration on the Beinn Buidhe slopes, which is far in excess of what would be likely to be brought about by the small granite intrusions that appear on the surface. The western boundary of the Glenfyne granite is roughly coincident with Glenfyne. The dykes of orthophyre and porphyrite occupy a zone about a mile in breadth, and extend to about six miles south-west from this granite. None of them are seen to pass into the granite, but the porphyrites bear such a strong petrographical resemblance to it that there can be little doubt that they represent the dyke phase of that rock.

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The distribution of the small igneous bosses, however, is somewhat different. They are scattered westwards from the Glenfyne granite over a broad tract of mountainous country extending to Glen Shira. If we except two small bosses of diorite which occur somewhat outside of this zone at about six miles south-west from the Glenfyne granite, it may be stated generally that the granite and diorite bosses occupy the part of the belt nearest to the granite, while the olivine-monzonites occur in the outer zone, the central part of the belt being more or less common to both, so that while the monzonites extend to a distance of about four miles from the granite, the small bosses of granite and diorite are restricted to a zone extending about two miles from the Glenfyne granite. Again, the lamprophyres of monzonite type are most strongly developed in the monzonite area, but also extend in a northward direction as far as Dalnally, helping still further to bridge over the interval between the main granite masses of Glenfyne and Ben Cruachan.

Before entering further into a description of these olivine-monzonites and their allied rocks, it will be convenient to state briefly the sense in which the term monzonite is here used. While this group of rocks bears marked affinities to the rocks described by Brögger as monzonites from the district of Monzoni, the Argyllshire type-rock is more basic, and always contains olivine, and while the olivine-bearing monzonites would represent only a basic variety of Brögger's group, in Argyllshire this represents the type-rock. But in other respects they resemble so closely the monzonites of Brögger that the term olivine-monzonite, first applied to them by MR. TEALL,* has been adopted. As shown by MR. TEALL,† these rocks are allied to both pierites and to monzonites, the amount of augite and olivine linking them with the former, and their proportions of silica, alumina and magnesia with the latter. MR. TEALL further pointed out that the augite from the rock mapped by MR. GRANT WILSON near Ballachulish was of the same type as that occurring in the "augite-syenites" of Monzoni. While, again, some of the rocks from the Loch Awe and Inveraray district exhibit a more or less equal amount of orthoclase and plagioclase, and in this respect approach closely to the monzonites of

* *Op. cit.*, p. 23.

† *Op. cit.*, p. 22.

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Brögger; this character is by no means persistent in them. In some good olivine-monzonites, fairly typical of the Argyllshire rocks, orthoclase has diminished to a very small proportion as compared with the plagioclase, and this diminution holds good whether or not the rock is rich in olivine.

In the field these monzonites present a characteristic appearance. They occur as more or less lenticular-shaped masses, like coarse dolerite, with a strong tendency to weather into cup-shaped depressions or deep hollows. In decomposition, however, they bear a striking contrast to dolerites; their outer surfaces are remarkably fresh, and ring somewhat like phonolite when struck with the hammer. They are dark in colour, and their constituent minerals can be readily detected with the naked eye. Pale green olivine in fairly large rounded grains can be seen amongst the more conspicuous dark augite and brown biotite, the felspar being less conspicuous. Perhaps the most characteristic mineral which strikes the eye is the biotite, in a discontinuous, patchy condition, but with the patches in optical continuity. When hypersthene is present, it can generally be readily detected without the assistance of a lens. Sometimes large patches of the rock are almost entirely feldspathic, but these bear an insignificant proportion to the mass as a whole, which is generally fairly uniform throughout.

In this Beinn Bhuidhe region there are two well marked examples of the typical olivine-monzonites. One mass occurs in the Brannie Burn a mile south-south-west of Beinn Bhuidhe, the other in the Allt an Sithein, a tributary of the Shira River, about $2\frac{1}{2}$ miles west of Beinn Bhuidhe. The olivine-monzonite in the Brannie Burn extends for a length of about half a mile in a broad lenticular mass. Its boundaries are largely obscured by drift, but its general outline can be sufficiently made out by its junctions with the schist seen in the main burn and its tributaries. It has been intruded in the well-marked zone of garnetiferous mica-schist, which has been traced across the Highlands, occupying a position between the Loch Tay limestone and the Ardrishaig series. This is a typical olivine-monzonite, dark grey in colour, medium-grained in texture, and with the usual rugged type of weathering. Olivine in good-sized grains is conspicuous; the biotite is likewise prominent amongst the augite and felspar; while ophitic orthoclase is exceptionally well developed. The rock has produced well-marked contact alteration in the garnet-schist, good hornfels having been developed for a distance of 15 or 20 yards from its margin. In the hornfels zone fresh bright red garnets are seen, which appear to have resulted from the re-crystallisation of the garnets that were present in the schist before the monzonite intrusion. The eruptive rock is fairly uniform throughout, but contains inclusions about six inches wide of very much finer grained material. There is also a zone about six feet wide within the mass, mainly made up of feldspathic material, which probably represents the more acid condition of the magma; it passes insensibly into the normal rock, and is not unlikely to be of sedimentary origin, as it differs both

in composition and in the absence of the hornfels alteration from the sediments on the margin of the mass.

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Perhaps the most interesting point in connection with this olivine-monzonite is the occurrence of a granite in the heart of the rock, as exposed in the small burn that flows through the northern part of the mass. The precise outline of the granite cannot be determined owing to the presence of drift, but the distance of its two outer margins from each other, as exposed in the burn, amounts to about 170 yards. It is a fine-grained hornblende-biotite-granite, of the type common in the Beinn Bhuidhe district. Its intrusive character into the monzonite is unmistakable, as it sends veins into it from its margin, while veins of granite six to nine inches wide traverse the monzonite.

The next exposure of the rock occurs at An Sithein, and this mass is rather smaller than that of the Brannie Burn, since it is little more than a quarter of a mile in length and about one-sixth of a mile in width. It has been intruded into the Ardrishaig series—a zone of calcareous sericite schists. Here the conditions for regional metamorphism were less favourable than in the schists at Beinn Bhuidhe, and the rocks therefore were neither so indurated nor so crystalline when the intrusive rock was injected into them. As a consequence the monzonite has been able to effect greater contact-alteration; the change into hornfels extends to about twenty yards from the intrusion, and is specially marked. In general character this dark grey, medium-grained olivine-monzonite is similar to that just described. It contains, however, not only olivine, but hypersthene, and is therefore a connecting link between the monzonites and the hyperites. Like the rock of the Brannie Burn it incloses small zones of more highly felspathic material. At its eastern boundary it is much coarser, owing to the augites being much larger than in the normal rock, and occurring in a porphyritic condition. This rock, like that already described, has been cut by a later intrusion; while the Brannie Burn mass was invaded by a granite, this mass has been pierced by a lamprophyre dyke.

A rock which, in the field, can be seen at once to belong to the monzonite group, occurs half a mile north-west of Clachan Hill, and about a mile from the Brannie Burn mass on the steep slope between that hill and stream. It is a large sill-like intrusion, about half a mile in length, and one-eighth of a mile in width, and strikes at the Brannie Burn rock, from which it is separated by a space of three-quarters of a mile. This mass, while closely allied to the olivine monzonites, is an augite-diorite. MR. TEALL, who examined it under the microscope, describes it as being composed of nearly colourless augite, biotite, hornblende (green), plagioclase and a little interstitial quartz. Alkali felspar has not been definitely recognised, and only a very small quantity can be present. The augite is of the type occurring in the monzonites. Although not itself a monzonite, the rock belongs to that group.

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A small sill close to the mass just referred to evidently belongs to the same group. It contains no augite, and has been determined by MR. TEALL from microscopic examination to be a biotite-camptonite, exceptionally rich in ferro-magnesian constituents. There can be little doubt, however, that it is closely related to the rock last described, and represents a more basic intrusion from the same magma. Further, this rock must be regarded as a connecting-link between the lamprophyres and the monzonites. In the Brannie Burn ground the monzonite and augite-diorite are associated with large numbers of lamprophyres, which immediately succeed them and extend in a westerly direction to Glen Shira. These rocks occur in close proximity to the augite-diorite and monzonite, and many of them shade so indefinitely into them that we must suppose them to represent the dyke phase of the monzonite group.

Two small lamprophyre sills on the slope of Ceann Garbh, about two miles to the north-east of Beinn Bhuidhe, are in some respects peculiar. They occur near one another, are dark in colour and medium-grained, but contain porphyritic crystals of augite and platy plagioclase, and are undoubtedly allied to the monzonites. They are, however, distinctly more porphyritic than the typical monzonites, and in mode of occurrence are more closely akin to the lamprophyre division of the monzonite group. Under the microscope they are seen to contain fairly large phenocrysts of colourless augite and plagioclase, in a matrix of felspar, biotite, and magnetite (accessory), with which chlorite and other secondary minerals are associated.

Another example of a lamprophyre sill of monzonite type appears a little to the south of Dalmally. It closely resembles both the two examples just described from Ceann Garbh and the augite-diorite from Clachan Hill. It is an augite-lamprophyre that clearly belongs to the monzonite group. As the two sills from Ceann Garbh might equally be classed with the monzonites or with the lamprophyres, so this sill might be placed either with the augite-lamprophyres or the augite-diorites, seeing that it occupies a position somewhat intermediate between the two, the rocks from all these localities being unmistakably members of the monzonite group.

In like manner a passage may be traced between the lamprophyres of pronounced monzonite type and the lamprophyres of the typical camptonite type. These intermediate stages can be favourably studied amongst the numerous lamprophyres of the Brannie Burn. In some instances augite is as conspicuous as hornblende, while in others hornblende only occurs, and we get the typical camptonite or hornblende-lamprophyre of this district. In some sills phenocrysts of altered augite and brown hornblende may be seen in a matrix of the lamprophyre type, while in others, by the absence of augite and the addition of biotite, we get a biotite-camptonite. Some of the sills, again, are made up of material similar to the ground-mass of these camptonites, and by the gradual diminution of the hornblendes we reach a type of lamprophyre prevalent in the district.

The monzonites, although most common amongst the more basic rocks of the district, are not wholly confined within such range. An instance will now be described in which a monzonite forms a portion of a mass which, taken on the whole, is a hornblende granite or a tonalite. About a mile and three quarters south of Beinn Bhuidhe two small bosses occur at rather more than a mile from the boundary of the Glenfyne granite, but not more than a third of a mile from the schist which is veined by the granite. The larger mass is about a quarter of a mile in length and one eighth of a mile in width. The smaller and more northerly mass, only separated from it by a distance of 100 yards, is about 200 yards long and about 100 yards wide.

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These masses of fine-grained granite are slightly variable in composition and texture. In some parts the material is a grey biotite-granite or granitite, containing zonal plagioclase and interstitial quartz and orthoclase, in other parts hornblende appears. Moreover, the outer portion which is finer-grained is much darker and the amount of hornblende in it must be greater. Indeed it would appear that the margin of the mass is probably more basic than the interior, and since plagioclase feldspar is in excess, parts of the mass might be more fittingly called diorite. Besides hornblende, augite is sometimes present. The specimen which MR. TEALL examined was composed of more or less idiomorphic augite, biotite, lath-shaped plagioclase, interstitial quartz, and orthoclase, with some accessory magnetite and secondary hornblende and chlorite. This rock is allied to both olivine-monzonite and to hyperite. Augite diorites occur in the monzonite group. MR. HILL believes that the group may have a still further extension and embrace the more acid diorites and hornblende granites.

The district includes rocks still more acid than those now described. They consist of grey fine-grained biotite granites, forming small protrusions on the ridge and flanks of Beinn Bhuidhe, one of which has already been referred to as an intrusion in the olivine-monzonite of the Brannie Burn. There is every reason to suppose that these biotite-granites and hornblende-granites are of the same age as the Glenfyne granite, on the border of which they occur, and the finer-grained portions of the Glenfyne granite is identical in character with the material of these smaller intrusions.

While the instances here cited of a monzonite being pierced by granite and by a lamprophyre afford an indication of the relative ages of the rocks, they supply no evidence to determine the relation of the granite and lamprophyre to one another. This, however, has been apparently settled on the northern flanks of Beinn Bhuidhe, where a granite pierces a lamprophyre. The lamprophyre sill is distinctly seen to be veined by the granite which has produced great contact-alteration on it. Under the microscope the older rock is found to be composed of small scales of contact-brown-mica and water-clear plagioclase crystals, and crystalline patches of hornblende are also seen.

From the occurrences and behaviour in the field of this in-

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teresting group of rocks, we may now proceed to consider how far they help in determining the relations of the various igneous rocks apparently scattered at random over the wide district of rugged and somewhat precipitous hills, amongst which the highest peak, Beinn Bhuidhe, rising out of Glenfynè, attains within the space of 2 miles from its base an elevation of over 3,000 feet. The rocks enumerated in the foregoing pages range from acid to basic in composition, including granite, quartz-diorite, augite-diorite, augite-camptonite, camptonite, lamprophyre, and olivine-monzonite, which are so closely connected from a petrological standpoint that they pass by insensible gradations into one another. We have seen that the monzonite type prevails over the entire series, linking them together as a connected whole. This prevailing monzonite type, embracing rocks so varying in composition, is strong presumptive evidence that the rocks represent various phases of material which has been derived from a common magma. Further direct proof has been obtained of the intrusion of different members of the group into one another, thus affording an indication of the order of the successive phases of injection. If this apparent order accurately represents the true sequence of events, the olivine-monzonites would appear to have been intruded first, followed by the lamprophyres, and finally by the granite, or in other words, that the more basic material was intruded earliest, and the most acid latest. Whether the smaller igneous masses of the Beinn Bhuidhe area coincide in age with the large granite mass of Glenfynè cannot be with certainty maintained, but, as stated already the smaller granite masses appear to be identical with the finer-grained portions of that granite, and the porphyrites which occur amongst them are so closely allied to it, that there can be little doubt that they represent its dyke phase. On the whole there are strong grounds for supposing that all these granite masses are approximately of the same age.

The study of this group of rocks throws some light on the age of the lamprophyre-dykes so generally scattered over the Highlands. So far as the lamprophyres of this district are concerned, the evidence is ample that, like the olivine-monzonites, they have been derived from the more basic portions of the magma, which afterwards supplied the material for the granites. It is not suggested that all the lamprophyre-dykes are necessarily of the same age, nor that each granite mass was intruded at precisely the same time. Some of the lamprophyres are possibly later than some of the granites, but we have no reason to doubt that the order of succession here described holds good generally—at any rate the evidence is absolutely conclusive that some lamprophyres have preceded the granite of their vicinity.

Allusion has been made on a previous page to a group of porphyrite-sills extending to the south-west of the Glenfynè granite, some of which undoubtedly represent the dyke-phase of that rock. They are of three types, viz., orthophyres, porphyrites, and mica-porphyrtes. The orthophyres are not so strongly developed as the porphyrites. They are rather unsatisfactory in

character, the decomposition of their feldspars having proceeded so far that it is not always possible to decide whether this mineral is orthoclase or plagioclase. The porphyrites are of two types and of different age. The mica-porphyrates are sometimes cut by the hornblende-porphyrates. They were themselves originally hornblende-porphyrates, in which the hornblendes are now represented by pseudomorphs of biotite and epidote. MR. TEALL has suggested that the alteration has been brought about as a result of contact or thermo-metamorphism, as hornblendes frequently decompose to aggregates of chlorite and epidote, while chlorite may be converted into biotite by contact or thermo-metamorphism. Certainly the evidence previously adduced of the alteration of a lamprophyre by contact-metamorphism is suggestive, the hornblende-lamprophyre being converted into a rock made up of water-clear feldspar and contact-brown-mica. As regards the porphyrites there is no evidence of such contact-metamorphism, except that they occur amongst schists, in which the regional metamorphism is beginning to be rapidly increased, and it is possible that thermo-metamorphism may have been the agency responsible for this increase of regional metamorphism, and that the porphyrites were affected at the same time.

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The rocks of the later group of hornblende-porphyrates are comparatively fresh, and vary largely both in their texture and porphyritic characters. The finer-grained varieties are hornblende-porphyrates, containing sphene; the porphyritic feldspars are plagioclase, similar to the idiomorphic feldspars in the Glenfyne granite, which also contains sphene. They generally also contain free quartz, sometimes in considerable quantities. As they become coarser in texture, they pass into quartz-diorite or hornblende-granite, and it may be noted in this connection that the coarser and more granitic varieties enter the zone of the monzonite group, the true dyke-rocks being most prevalent to the south-west, at and beyond the limits of this zone. A sill which occurs on Clachan Hill, about three miles south-west of Beinn Bhuidhe, is composed of hornblende, biotite (idiomorphic), and more or less lath-shaped plagioclase, alkali feldspar, and quartz with sphene, apatite and iron ores as accessories. This rock is richer in ferro-magnesian minerals and plagioclase than a specimen selected as typical from the Glenfyne granite, and is somewhat intermediate in structure between granite and porphyrite. This group of hornblende-porphyrates somewhat differs in character from the porphyrite-dykes of the Loch Awe district, which MR. KYNASTON supposes to represent the dyke phase of the Cruachan granite. On the whole, the rocks which it embraces are more acid and contain a larger amount of quartz which is clearly distinguishable without the aid of a lens.

Although the Glenfyne granite has its own assemblage of smaller intrusions, dykes, and sills distinct from those belonging to the Cruachan granite, there are well-marked resemblances between these two great granite masses. Thus MR. KYNASTON has recorded augite-diorite from the district of Ben Cruachan, while according to MR. HILL's observation, the igneous masses

of the Beinn Bhuidhe area are suggestive of an underground connection between the granites of the two mountains. As regards the age of the Glenfyne granite, no definite statement can be made, except that it must be later than the foliation of the schists.

Glen Etive
and district
between
Black Mount
and Glen
Shira. (Mr.
Kynaston.)

The mapping of the Glen Etive granite was completed, and its boundary line was carried from Glenkinglass past the western end of Loch Dochart and thence in a general north-westerly direction to Lairig Dochart, where the line was joined up with that traced from Glen Etive in 1898. The rock has not presented any new features. The completion of the boundary-line shows that this granite forms a well-defined oval mass, almost completely surrounded by the Ben Cruachan type. It includes an area of approximately $60\frac{1}{2}$ square miles, and is only covered to an insignificant degree by morainic material and other superficial accumulations. It is characterised by a wild and imposing type of mountain scenery, embracing no less than five peaks more than 3,000 feet in height.

The Ben Cruachan type of granite was found to die out against the Glen Etive mass in Glenkinglass, about a mile east of Doire-nan-Saor. Following, however, the margin of the latter type north-eastwards for two miles, we again find the Cruachan type about a mile south-west of Loch Dochart. It rapidly widens from a breadth of only a few yards to nearly half a mile, and assumes a fairly coarse texture. It is a pinkish hornblende-granite, becoming fine-grained and dioritic in appearance at its junction with the quartzose schists to the east. North of Loch Dochart the boundary-line was traced in a general north-easterly direction to within a hundred yards or so west of the summit of Stob Ghabhar (3,565 feet). This portion of the Cruachan granite is continuous with that already mapped in Glen Etive, and it still maintains characters similar to those previously described from the Ben Cruachan district. In some places, for example, on the east side of the Dochart Burn, it appears to pass gradually into the Glen Etive granite. Its texture does not change as the margin is approached and the two types of rock pass gradually into one another, so that no hard-and-fast line can be drawn between them. A similar passage has already been noticed as occurring to the west of Loch Etive.*

Outside the eastern margin of the Cruachan granite a separate mass, of a similar general type, has been mapped in the immediate neighbourhood of Clais-gobhair. It is exposed for a mile and a half in the Clais-gobhair Burn, and is continued north-eastwards as a narrow strip to the north-western margin of Sheet 46. The rock is a medium-grained greyish, and sometimes pinkish, hornblende-granite—or, perhaps more strictly speaking, a diorite of the tonalite type. Close to Clais-gobhair an oval mass of a coarse very hornblendic diorite occurs within it, and doubtless represents a basic modification; while another small mass of a more basic diorite occurs among the schists close to its eastern

* *Summary of Progress for 1898*, p. 79.

margin. Under the microscope the normal type of the hornblende granite [Slide, No. 8620, half a mile north-west of Claisgobhair] is seen to consist of plagioclase felspar, green hornblende, biotite, and a small proportion of alkali felspar and interstitial quartz; sphene, apatite, and iron ores occurring as accessories. The basic modification which occurs within this mass varies from a fairly coarse rock, containing about equal proportions of hornblende and plagioclase, to a coarse hornblende rock in which scarcely any felspar is visible to the naked eye. The former variety is seen under the microscope [8621] to be in great measure made up of large plates of green hornblende, which include small idiomorphic plagioclases and some small flakes of altered and ragged biotite. A few small pyroxene grains are also present, while hornblende and plagioclase likewise occur interstitially between the large plates of hornblende. There is no quartz. The other intrusion occurring outside the hornblende-granite is a similar rock, though the proportion of felspar to ferro-magnesian constituents is apparently more uniform. Further to the east again lies the diorite of Rannoch Moor, which doubtless, when more fully investigated, will turn out to have close affinities with the hornblende-granite and diorite of Ben Cruachan and the Black Mount.

Glen Etive and district between Black Mount and Glen Shira. (Mr. Kynaston.)

As regards the age of the Cruachan granite, which has been referred to in the Reports of former years,* no fresh facts of any importance have come to light this year. MR. KYNASTON has examined microscopically the andesite which occurs in the Pass of Brander at a distance of about three-quarters of a mile from the nearest exposure of granite, but could detect in it no positive signs of contact-metamorphism. The andesite is not found in this district any nearer to the granite than this point, and it never occurs on the north-east or Cruachan side of the Pass of Brander fault. It is to be hoped, however, that more definite facts concerning the chronological relations of these two rocks will be forthcoming as the work in this and other parts of the district advances.

In connection with basic modifications of the larger masses of intrusive rocks attention may be called to the occurrence of olivine-monzonite on the west side of Glen Orchy. An elongated patch of this rock, almost a mile in length and an eighth of a mile in breadth, besides two smaller oval patches, probably connected with it, was mapped about a mile north of Catinnis in Glen Orchy, and seven miles from Dalmally. The rock varies from a medium grain, weathering like dolerite, and consisting apparently in large measure of augite, to a coarse-grain, in which the constituent minerals, olivine, augite, and biotite are easily seen with the naked eye. This coarse rock forms the greater part of the mass, and weathers into the characteristic small cup-shaped depressions already noticed by MR. HILL. Under the microscope [8614] the olivine is seen to occur mostly in rounded grains, and seldom shows crystal outlines. It is fairly fresh, is traversed by

* *Summary of Progress* for 1897, p. 85 ; for 1898, p. 76.

Glen Etive
and district
between
Black Mount
and Glen
Shira. (Mr.
Kynaston.)

numerous anastomosing veins of magnetite, and often occurs as inclusions in the augite. Augite and olivine appear to be present in about equal proportions, and, together with biotite, form the main mass of the rock. The augite chiefly occurs as large individuals with well-defined crystal outline, frequently showing a marked zonal structure under crossed nicols. It also appears in smaller grains and granular aggregates of irregular contour scattered throughout the slide. The biotite is strongly pleochroic and occurs in ragged flakes and patches, and several detached flakes are often seen to be in optical continuity. Felspar, together with some biotite and small augite-grains, fills up the interspaces between the larger individuals. Both orthoclase and plagioclase are present, the latter being distinctly idiomorphic, while the former is interstitial. Magnetite fills the veins in the olivine, and appears also as grains associated with both the olivine and biotite. MR. KYNASTON has likewise visited the Beinn Buidhe district described by MR. HILL (p. 48), and agrees with his colleague that so far as the present known evidence goes, it may not be unreasonable to conclude that the monzonites have been derived from the basic portion of the magma which supplied the granites, and are, therefore, approximately of the same geological age.

Throughout the whole area surveyed by MR. KYNASTON last year a large number of dykes and sills, having petrological affinities with the larger granitic masses, have been mapped. These show a wide range of variation both in composition, structure, and the relative proportion of the different constituents. They include quartz-porphyrines, felsites, porphyrites, diorites, and lamprophyres, and these pass into one another through intermediate varieties. As regards distribution it is noticeable that the more acid types of sills are almost always found nearer the granite than the more basic varieties. The lamprophyres, however, frequently occur in the neighbourhood of the Ben Bhuidhe granite, and diorites occasionally cut that of Ben Cruachan.

The quartz-porphyrines are found on Ben Mhic Monadh, about the head of Glen Strae, and in the Black Mount district. They traverse the schists and the Cruachan type of granite, but are not seen to cut the Glen Etive type. The usual type is a biotite-bearing quartz-porphyrine, containing a certain amount of plagioclase as well as orthoclase. These, by an increase in the amount of plagioclase relatively to orthoclase and the disappearance of the quartz, will pass into porphyrites.

The porphyrites are common in the Glen Strae and Black Mount portion of the district surveyed, and also occur, but more sparingly, in other parts. They comprise both biotite and hornblende-porphyrines. The former pass occasionally through intermediate varieties into orthoclase-porphyrines or orthophyres and quartz-porphyrines, and the latter merge into diorites. Good examples of the more acid type of porphyrite are found in the neighbourhood of Clais-gobhair, and some of these are so crowded with phenocrysts as to have the appearance at first

sight of a granitic rock. A specimen from Meall Buidhe shows abundant phenocrysts of felspar, biotite, hornblende, and small quartz-grains in a fine greyish matrix. Under the microscope [8624] all the larger phenocrysts of felspar are seen to be plagioclase, and to be in excess of orthoclase which occurs in smaller crystals. Quartz occurs sparingly in small, rounded grains. The biotite is seen as plates with ragged outline, and is also scattered throughout the rock in peculiar groups and patches of small flakes. These groups are frequently associated with hornblende, and would appear to be replacing it owing to some secondary action. The hornblende is pale green and occurs in irregular patches and grains, which never show crystal outlines, and the patches appear as a granular aggregate beneath crossed Nicols. Occasionally these patches have a more defined form, but they are always associated with numerous small flakes of biotite and grains of magnetite. Apparently there has been a gradual breaking down of the hornblende, and it is now partially replaced by secondary biotite and magnetite. Both the original biotite and hornblende occasionally occur as inclusions in the felspar. The groundmass is a micro-crystalline quartzofelspathic aggregate with small disseminated grains of biotite and hornblende. Magnetite is an accessory. Another variety of hornblende-porphyrite with acid tendencies is common in the Cruachan granite on the ridge to the west of Stob Ghabhar, near Clais-gobhair. Elongated crystals of hornblende and plates of biotite are easily seen with the naked eye, while the felspar phenocrysts sometimes range up to an inch in length. The microscope shows [8623] that some of these latter are evidently orthoclase, though the larger proportion of the felspar phenocrysts are plagioclase. The hornblende is fresh and occurs in well-defined elongated crystals. The biotite is in about the same proportion as the hornblende and frequently occurs in hexagonal plates. Quartz occurs as an accessory; but is not visible to the naked eye, and only appears in occasional small rounded grains. The groundmass may be described as micro-dioritic. It shows much idiomorphic plagioclase, small greenish hornblendes, and biotite, with interstitial felspar and quartz. Porphyrite of this type has already been noticed from the same district.* These rocks appear to have closer affinities with the Glen Etive type of granite than with that of Cruachan.

Glen Etive
and district
between
Black Mount
and Glen
Shiela. (Mr.
Kynaston.)

Diorites and micro-diorites, in which plagioclase and hornblende may often be porphyritic, are common as sills in the Glen Orchy part of the district and in the Black Mount. These appear more frequently in the schists than in the granite. An unusual type, but well-marked when it occurs, is found on Meall an Laoigh, three miles south of Clais-gobhair. It is an augite-diorite with conspicuous and well-defined porphyritic augites, giving the rock a peculiar spotted appearance. Sills of a similar rock have also been mapped on the high ground separating Glen Strae from

* *Summary of Progress for 1898*, p. 39.

Glen Etive
and district
between
Black Mount
and Glen
Shira. (Mr.
Kynaston.)

Glen Kinglass.* The intrusions of this rock usually form larger sills than the porphyrites. In one instance, on Ben Larachan a plug-like mass of the rock was mapped, roughly circular in outline. This porphyritic type of augite-diorite is not known to cut the granite. The proportion of felspar to augite and hornblende often varies considerably; it is in the more felspathic varieties that the spotted appearance above referred to is so marked. Under the microscope, a specimen [8622] from Meall an Laoigh, shows large porphyritic augites resembling the augite of the monzonites, though not so fresh, with well-defined crystal outlines and zonal structure seen under crossed Nicols. Marginally they are partially replaced by greenish hornblende. The rest of the rock is dioritic in appearance, and consists of plagioclase, green hornblende, biotite, and some accessory magnetite. The biotite appears in scattered flakes, often in groups in optical continuity, recalling a similar feature in the monzonite. This appearance seems to be due to the biotite being moulded on the felspars. The plagioclase is mostly idiomorphic, and there would appear to be also a certain amount of interstitial orthoclase, though all the felspar is so turbid from decomposition that this point cannot be definitely determined. It is interesting to note certain apparent points of relationship between this type of augite-diorite and the monzonites. The addition of olivine and the elimination of the hornblende would give a rock resembling the olivine-monzonite of Glen Orchy. Its mode of occurrence also resembles rather that of the monzonites than that of the ordinary porphyrite and diorite sills. The sill-like mass of this rock on Meall an Laoigh is cut by two small intrusions of quartz-porphyry.

The lamprophyres constitute a rather ill-defined group, between which and the diorites and porphyrites there seems to be no hard and fast line. They are found in large numbers in the Glen Shira and Ben Bhuidhe parts of the district, but in a northerly and north-westerly direction from the upper end of Glen Shira they gradually die out, and only occasionally occur among the hills between Glen Orchy and Glen Stræ. Many of them have already been mapped and described by MR. HILL. Frequently they are highly micaceous, resembling typical mica-traps. Varieties containing a large proportion of hornblende are common. A sill, previously mapped by MR. HILL, north-north-west of Corryghoil, near Dalmally, is seen under the microscope [8615] to be a typical camptonite. It contains abundant idiomorphic brown hornblendes in elongated crystals, plagioclase, orthoclase, interstitial quartz, and accessory magnetite. Sills of this type are numerous in Glen Shira, Glen Orchy, and on Ben Sroine, between Glen Orchy and Glen Lochy.

Kilmelfort
district. (Mr.
R. G. Symes.)

During the past year MR. SYMES has continued his survey of the district between Oban and Loch Melfort. To the south of the area of the Lorne volcanic rocks, from Kilmelfort as a centre, he has mapped the schists and other crystalline rocks, which

* *Summary of Progress for 1897, p. 92.*

emerge from under the Old Red Sandstone series. In the Kilmelfort district. (Mr. Duchara Burn dark calcareous slates are met with, which display a metamorphosed character. They have been converted into calc-silicate hornfels, and they are associated with epidiorite and limestones. Interbedded with these strata at least one sill of intrusive epidiorite may be observed, but as the sedimentary rocks are very much folded, it is quite possible that the successive exposures of epidiorite may be due to the reappearance of the same sill owing to folding. Above the second bend of the stream grey and black slates are succeeded by the great sill of epidiorite which caps Carn Duchara (3½ miles south-east from Kilmelfort), the highest point of the ridge. The fact that limestones and black slates are found on one side of this sill, and grey slates and quartzites on the other, seems to point to an order of succession; and as MESSRS. HILL and Pocock have detected shale fragments in the quartzites, it may be inferred that the succession is an ascending one from the limestones to the quartzites.)

On the shore between Kames Bay, two miles south-west of Kilmelfort and Rudh'an Roin on the east, the schists have not been so much changed into hornfels as nearer the granite, to be afterwards referred to, but occur for the most part as phyllites with calcareous bands, which at one point swell out into bands of limestone, or perhaps dolomite, folded upon themselves so as to be repeated over and over again. Sometimes these folds are isoclinal, though they often appear to be regular, the direction of cleavage seeming to be almost invariable with a high south-easterly dip. South-east of Tralaig, three miles to the north-east of Kilmelfort, thick limestones without shales are folded with the epidiorites. These strata reappear to the east of Loch a' Chaoruinn and of Loch a' Mhinn, where they form a small escarpment on which lies the basal breccia of the Lower Old Red Sandstone. East of Loch na Sringe, seven miles north-east of Kilmelfort, thick limestones folded up with siliceous schists, epidiorite, and black slates, are overlain unconformably towards the north-west by the andesitic sheets of the Lorne volcanic series. Most of these limestones could be used for economic purposes. West of Loch a' Chreachain (three miles east from Kilmelfort), and of Loch a' Chaoruinn, numerous thin bands of limestone again form rapid folds with epidiorite and black schists, and on the south pass under the Lower Old Red Conglomerate, from which they again emerge at the southern outcrop of the conglomerate in Gleann Mor Burn. The calcareous members of the schistose series have a wide extension in this region. Ten miles to the south of Kilmelfort, in the road east of Salachary, limestones with pebbles of quartz sometimes an inch in diameter are flanked with schistose epidiorite.

Besides the limestones, the sills of epidiorite form conspicuous features in the geology of this district. Thus, the great sill of Carn Duchara, already referred to, is a thick sheet, which seems to be repeated in rather sharp folds. The rock of this sill is highly basic and rather fine-grained, so that it has been

Kilmelfort
district. (Mr.
R. G. Symes.)

susceptible of marked cleavage over the greater part of its extent, the cleavage-planes being nearly vertical, but inclined to the south-east. Near the top of the hill in several places grey slates are seen to be folded with the epidiorite, and again further to the north, beyond Loch a' Ghille, thin cakes of slate are seen adhering to the surface of the sill, and minutely crumpled along with it. If, as is probable, this marks the upper surface of the sill, it conforms almost exactly to the form of the ground. About quarter of a mile north-east of Loch a' Ghille a second sill, or perhaps a branch of the one under consideration, is quite like the first in texture, having porphyritic crystals scattered through the fine light-green groundmass. Along the north face of the hill the denudation of the folds in the epidiorite has exposed the underlying dark slates, which coincide with hollows, whilst the edges of the epidiorite sheets form crags. The first few feet of this sill lying next to the dark slates present a highly vesicular and amygdaloidal texture, the cavities being small and globular, and only elongated where they have been affected by the pressure which has been applied subsequent to the consolidation of the rock and the infilling of the vesicles. Where the kernels have weathered out the rock is so cellular as closely to resemble a lava, which the rock may possibly have been. The vesicular band follows each of the folds along which the black slates are exposed. On the south-western face of the hill the foldings seem to be more intense, for the upper porphyritic layers of the sill which make up the greater part of the ridge plunge at once vertically downwards, and are succeeded by grey flaggy slates, like the rock that adheres to the surface of the epidiorite, but quite unlike the underlying black slate associated with limestones. As to the rock of the hill itself, it is basic, fine-grained both above and below, and coarse-grained in the middle. In many parts the fine-grained rock has been cleaved into chloritic and epidotic slates or flags. Even where the rock is not much deformed by cleavage, it is highly epidotic and chloritic, which gives it a light sage-green colour. It also supports a crust of light-coloured lichen, which makes its crags conspicuous.*

To the east of Loch Pearson, close to Kilmelfort, epidiorites are again seen to be folded with quartzites, siliceous schists, and occasional phyllite bands. The quartzites dip about 15° east, their schistosity is inclined at an angle of about 80° . MR. TEALL, to whom specimens were submitted, remarks regarding the epidiorites of this place, "that they are not typical epidiorites, but being so closely allied to them must be grouped along with them." One of the specimens he describes as epidiorite (amphibolite, with zoizite and epidote), and of another he writes that "it contains chlorite, biotite, water-clear felspar, and a little quartz." Around Kilmelfort the epidiorites form great ridges,

* It may have been this highly epidotised rock, or some similar mass, especially the very vesicular part that has been the source of certain vesicular epidotic basic rock-pebbles in a conglomerate on the Island of Kerrera. See *Summary of the Progress of the Geological Survey* for 1897, p. 83.

that stretch in the direction of the schistosity of the metamorphic rocks, the phyllites, quartzites, and limestones having been denuded on the lower ground. The tops of the ridges are strewn with massive angular blocks of the epidiorite. Kilmelfort district. (Mr. R. G. Symes.)

The most novel and interesting feature in MR. SYMES' recent surveys has been the discovery of a number of previously unobserved bosses of granite rising through the schists in the Kilmelfort district. These granites may be of the same age as that of Ben Cruachan, and they have produced a similar metamorphism in the surrounding sedimentary rocks.

Up to the present time six exposures of granite have been mapped to the south, east, and west of Kilmelfort. These are not improbably all extrusions from the same magma underneath. One of them occurs on the high ground four miles south-west from Kilmelfort, between Kames farm and Asknish on the south side of Loch Melfort. Another appears in the low ground at Tullich Farm, near Kilmelfort. Two hundred yards east of the manse a small exposure may be seen in the road leading to Loch Avich. Two other outcrops were noted in Gleann Domhain, four miles to the south-east of Kilmelfort, while one was found on the north shore of Loch a' Chaourinn three miles east from that village. Besides these bosses numerous veins cut the schists and epidiorites, and convert the former into hornfels. The granite, in all cases, is fine grained, with a preponderance of biotite, and the occasional occurrence of hornblende. In no part of this district has the granite been observed to make its appearance close to the Lower Old Red Conglomerate, nor have any blocks of it been found in that formation. MR. PEACH, who inspected the ground surveyed by MR. SYMES, found that "the Tullich granite is remarkably like some of the small bosses which occur about the Loch Doon granitic mass in Galloway." The phyllites as they approach the granite become a dark micaceous hornfels, and the calcareous beds are altered into calc-silicate-hornfels. Near the granite some of the strata assume a coarse gneissose structure, and probably contain cordierite.* At the south-east corner of the Tullich mass a dyke-like projection of the decaying granite appears to truncate a sill of felsite, showing flow-structure, intercalated between the bedding planes of the hornfels. The form of the granite mass suggests that the visible rock is the top of a boss from which the schists have not been entirely removed. In its centre a patch of schist may be seen adhering to the granite, while the schists are pervaded in every direction by strings of fine-grained granite, and, moreover, fragments of the schists have been floated off into the granite. The fine-grained character of the eruptive rock favours the supposition that nowhere is the granite now exposed far from its original margin.

On the hill-slope above Tullich, near the northern edge of the granite, a dyke of porphyrite about two feet across, and showing chilled edges, cuts the granite. A little farther down

* See *Summary of Progress* for 1898, p. 86.

Kilmelfort
district. (Mr.
R.G. Symes.)

the slope a sill of felsite with flow-structure has been intruded along the bedding planes of the schists (here altered into hornfels), and appears to be truncated against the margin of the granite. As this sill, like that on the south-east corner, does not penetrate the granite, the granite would seem to be later than the felsite. It may be added that a vein of the granite occurs in the hornfels near the farm of Tullich on the west side of the felsite sill, as if the sill were cut by the granite, though the actual junction of the two rocks is not observable. The little isolated granitic mass on the road two hundred yards east of the manse changes the phyllites into hornfels, and the limestone into marble.

In all the area surrounding the several granite masses, the schists have been converted into hornfels. The limits of this metamorphism are not easily definable. In some cases hornfels may be observed without the visible presence of any granite; it may therefore be inferred that there may be considerable bodies of granite below ground, which, though they have affected the overlying strata, have not yet been laid bare by denudation.

Among the various instances of the occurrence of monzonite already referred to (*ante*, p. 48), allusion was made to one observed by MR. SYMES. It forms a dyke twenty feet broad, running in a north-west and south-east direction south of Lochan a' Bhailis, six miles north-east of Kilmelfort. No other example of the rock *in situ* has yet been detected in the district. A large erratic, probably from the same dyke, but not from the same locality, is to be seen on the Avich road, a little north-east of Lagalochoan.

Two masses of highly crystalline porphyrite were mapped east of Kilmelfort. One of these occurs on the north shore of Loch Losgann Beg, and the other more to the east of Loch a' Mhinn. It may be inferred that from these sources the blocks were derived which form the bulk of the undermost layers of the Lower Old Red Conglomerate in that neighbourhood. At Rudh 'an Tighe Loisgte, east of Kames Bay, several sills of pink porphyrite may be noticed which do not quite follow the bedding of the schists, but often pass obliquely across from bed to bed. These rocks present close-grained or chilled edges against the schist, and at least one of them is vesicular in the centre. Porphyrite-dykes are rather uncommon in this district in comparison with the enormous number of Tertiary basalt-dykes. Three examples of them can be traced from the south-east of Kilmelfort, in a north-north-east direction, cutting first the limestones, phyllites, and epidiorites, further north rising through the Lower Old Red Sandstone and its volcanic series, then once more through the schists and epidiorites east of Loch Tralaig, whence they hold on to the north, again traversing the Lorne andesitic lavas near Oban, and then striking for Loch Etive. Nearly all the porphyrite dykes, but more especially those seen cutting the Lorne andesites and Lower Old Conglomerate, have a north-north-east and south-south-west direction. A mile and a quarter north of Kilmelfort a porphyrite-dyke that cuts both the

epidiorites and andesites assumes a columnar structure, where it traverses the lava sheets.

Kilmelfort
District. (Mr.
R. G. Symes.)

Nearly all the margins of the porphyrite dykes show under the lens flow-structure. For instance, in a gully half a mile south of Loch Losgain Beg the porphyrite dykes are edged with "fluxion-felsite." A large mass of felsite rises on the hill south of Kames Farm, near to the granite already referred to. Numerous dykes radiate from this felsite mass, which cut the metamorphic sedimentary series; but no felsite dykes have been found intrusive in the granite or Lower Old Red Conglomerate. On the east side of Loch nam Ban a rock has been noticed which has been identified by MR. TEALL as a lamprophyre, but its relations to the adjacent mass of porphyrite or felsite are not observable. Another dyke of lamprophyre cuts the epidiorite mass which bounds the felsite half a mile south-east from Loch nam Ban, and which has already been referred to as underlying the conglomerate, but here again the relations of the lamprophyre to the felsite are not shown. In the road section north of Lagalochan a dyke of lamprophyre as well as several of porphyrite are seen to cut through the epidiorite and the hornfels-rock in connection with it.

With the view of continuing and completing the survey of the Island of Jura in which MR. WILKINSON was engaged at the time of his transfer to England he was moved for a part of the year to Argyllshire, and he succeeded in mapping a considerable additional portion of Jura leaving no more than it is hoped will be finished during the present year.

Island of Jura
(Mr. S. B.
Wilkinson.)

The part of Jura surveyed by MR. WILKINSON last year lay chiefly on the western side of the northern half of the island, and embraced an area of thirty-one square miles. No new feature of importance has been noted by him among the rocks recently examined. The quartzite continues to display the same uniform appearance of the bedding, concealing the system of folds by which the strata are no doubt often repeated. The apparently continuous inclination is towards the south-east at between 30° and 40° . On the western coast line, however, from Ruintallain Point, the strata lie at a lower angle, and are seen to be rolling about considerably. Fine cliffs and crags of these rocks rise on the higher ridges such as at Rainberg Mor, Dhu Bheinn, and Bheinn Breac. The fine grained epidiorite dykes, formerly noticed on the eastern side of the northern area of Jura, have been found to extend westwards into the area surveyed during the past year. The three more or less parallel east-and-west dykes stretch across Gleann Cloisdale, and can be traced to Gleann Dorch where they seem to die out. The dyke of similar material which traverses the island from Ardlussa on the east across the top of Beinn Bhreac does not quite reach the western shore, but stops beyond the south-western slopes of a hill called Ceann Min na Beinne Brice, where it is joined by a basalt dyke which is in contact with it for a few yards. Another epidiorite occurs almost on the summit of the hill just mentioned, running in a north-

west and south-east direction. As formerly stated, although these epidiorite dykes have the same direction as the dolerite dykes of the Tertiary series, they are doubtless of much greater age.

Island of
Islay. (Mr.
Peach & Mr.
Wilkinson.)

Great difficulty having been experienced in the determination of the geological structure of the Island of Islay, especially of its central and northern parts, a strong effort was again made to discover the key to this complicated district before the publication of the map. Accordingly MR. PEACH joined MR. WILKINSON in a critical examination of the more important sections. Their re-examination was highly successful, as will be seen from the following account which they have prepared of the results obtained by them.

The coast section between Portaskaig and Bonahaven, which had been mapped in great detail, was again critically examined. Between Bonahaven on the north and Na Feamindean on the south (a point on the shore about a mile north of Portaskaig) the strata were found to comprise five groups in the following descending order:—

5. Sandy shales and flags with ripple-marks and worm-casts (like the "Fucoid Beds" of Sutherland and Ross), with massive beds of cream-coloured dolomite.

4. False-bedded blue and white quartzite with ripple-marks and vertical annelid-pipes—thickness 100 feet.

3. Sandy, rusty, ripple-marked and worm-tracked shales and flags, with a thin band of dolomite.

2. Quartzites with a band of conglomerate locally developed near the top, containing well-rounded pebbles of granite and other rocks similar to those in the Portaskaig Conglomerate.

1. Portaskaig Conglomerate, charged with well-rounded pebbles of granite, gneiss, quartzite, limestone, &c., in a sandy dolomitic and sometimes shaly matrix; with intercalations of rusty-weathering dolomite and bands of quartzite.

A small fault or line of crush appears on the shore near the junction of Groups 1 and 2, which probably does not seriously affect the original relations of the rocks.

The section from Na Feamindean, south to Portaskaig, is almost a counterpart of the sequence given in the foregoing table; the members of the highest Group 5, being visible at Na Feamindean, and the Portaskaig Conglomerate at Portaskaig. The local band of conglomerate at the top of Group 2 is, however, absent, and a fault, probably of no great amount, occurs on the shore near the junction of Groups 1 and 2. It is apparent, therefore, that an important structural fault runs inland from the shore at Na Feamindean, whereby the highest beds (Group 5 of table) are thrown down against the exposure of the Portaskaig Conglomerate to the north. In various sections between Portaskaig and Bridgend, the Portaskaig Conglomerate rests unconformably on the Islay limestone and the associated blue and black slates; indeed, the Islay limestone and slates have furnished a large proportion of the pebbles present in the exposures of the Portaskaig Conglomerate of that region.

From the evidence here given, it appears that calcareous rocks appear on at least three horizons in Islay in the following descending order :—

Island of Islay. (Mr. Peach & Mr. Wilkinson.)

- (a) Dolomites in Group 5 of table.
- (b) Lenticular bands of dolomite in Group 1 of table.
- (c) Limestone (Islay limestone) associated with blue and black slates, and unconformably overlain by the Portaskaig Conglomerate.

Sixty-nine specimens of calcareous rocks, taken from these horizons in Islay, have been tested by DR. POLLARD, who reports regarding them that the bands in Groups 1 and 5 are dolomites, while those associated with the slates beneath the Portaskaig Conglomerates are limestones.

The two confirmatory sections between Portaskaig and Bonahaven appear to indicate the original order of succession of the strata. After MR. PEACH'S departure, several weeks were spent by MR. WILKINSON in tracing the various subdivisions above enumerated over the inland area between Bridgend and Ruadh a' Mhail. The groups were found to be remarkably persistent, and to furnish valuable aid in working out the structure of that region. In general, it may be said, that they are repeated by a series of sharp folds, the long axes of which run north-east and south-west. In some cases, owing to faulting, only one limb of the fold is represented.

Island of Arran.

PROBABLE ARENIG ROCKS OF THE HIGHLAND BORDER.

In former Annual Reports of the Geological Survey reference has been made to the discovery of a band of rocks, possibly of Lower Silurian age, which have been wedged in along the fault at the Highland Border between the Lower Old Red Sandstone and the crystalline schists and grits.* These rocks have been traced at intervals from Kincardineshire to Dumbartonshire. They consist of graphitic shales, slates, or schists, black, grey and red cherts, and various dull green rocks of igneous origin, some of which are probably lavas, while others are intrusive. This association of black shales, cherts and volcanic and intrusive rocks, so closely a repetition of that which characterises the Arenig series over the Silurian uplands of southern Scotland, led to the suspicion that these Highland Border rocks might prove to be of Lower Silurian age. The suspicion was further strengthened by the finding of *Radiolaria* in the cherts, precisely as these organisms occur in the cherts of the Southern Uplands. A much more extensive development of probably the same belt of rocks has been detected far to the south-west in County Tyrone, where the igneous accompaniments are particularly conspicuous, embracing lavas, agglomerates and tuffs.†

* See *Annual Reports* for 1893, 1895, and 1896.

† A. Geikie, *Ancient Volcanoes of Britain*, vol. i., p. 240.

North Glen
Sannox. (Mr
W. Gunn.)

During the past year another link in the long chain of evidence has been found by MR. GUNN in the island of Arran, which thus connects the Stirlingshire section with those of Ireland. Though there is the strongest presumption that the rocks in question should be regarded as of Lower Silurian age, this account of an additional development of them is meanwhile retained in the present section descriptive of the Dalradian rocks, but further allusion will be made to them at the end of the account of the Silurian rocks (p. 82). MR. GUNN has supplied the following notes regarding their occurrence in Arran.

A strip of rocks that can be separated from the ordinary schists of the island, has been found to be well developed in the valley known as North Glen Sannox. It crosses the glen from south to north at a distance of rather more than a mile from the sea. It is upwards of a mile and a-half long, and from 100 to 400 yards broad, having its narrower width at the northern end. The rocks in this strip of ground, so far as can be seen, are not separated by any structural line from the ordinary schistose grits of the Highland series, which they follow with no apparent break. Nor do they differ in degree of metamorphism from the contiguous Highland schists. A closer examination, however, reveals some characteristic features which have not been met with among the schists, but which precisely resemble those already detected in the supposed Arenig rocks of the Highland border. They consist of black shales or schists and cherts, with some bands of igneous rock, which probably include both volcanic and intrusive bands.

The black shales and cherts are associated together as they occur in Stirlingshire, and also in the band of similar deposits intercalated with volcanic rocks in the Arenig group of Ayrshire. The black shales are partly in the condition of phyllites and much corrugated in places. The cherts are appreciably granulitized, and resemble in structure those portions of the cherts which approach the granite of the Southern Uplands. In this condition such rocks have usually had their organic remains obliterated. No trace of *radiolaria* has yet been found in the Arran cherts. The most prominent members of this group of rocks are those of igneous origin, and the important fact has now been definitely ascertained in Arran, that they include undoubted lavas and volcanic agglomerate. They occur intercalated with the black shales or schists, and cherts, as bands of a dull-green, decomposing material, which may be most conveniently named in the meantime "greenstone." Like their associated sedimentary accompaniments, they have undergone some deformation, and have passed into the condition of epidiorite. So far as the examination of the rocks has yet advanced, the whole of them, igneous and aqueous, are in the same condition of metamorphism as the schists to the north and west of them. They have an apparent dip to the east or east-south-east, stand at high angles, even as much as 90°, but there is no means of deciding which is top or bottom of the series. They have undergone much plication, which is specially observable in

the intercalations of black schist. They are flanked on either side by schistose grits of the ordinary Southern Highland type. The strip of rocks now described, is cut off at the southern end by the intrusion of the Arran granite, at the north-east end of Suidhe Fhearghas, while their northern boundary is a fault, which brings down against them a part of the Lower Carboniferous series. The schistose grits, which apparently underlie these rocks, are well exposed in the North Sannox Burn at the bridge, while another series of schistose grits, which apparently overlie them, can only be observed in the main stream, and on the south side of the glen, as they are cut out on the north side by the great Highland Border fault, which brings down the Lower Old Red Sandstone against them. This fault gradually crosses the line of strike of the igneous group, of which consequently only a portion is represented at its northern end.

North Glen
Sannox. (Mr
W. Gunn.)

The general succession of the members of this group of rocks, together with the overlying and underlying sedimentary strata of the Highland series, is apparently as follows, in descending order:—

1. Coarse schistose grits or gritty schists, weathering with a smooth surface.
2. Thin bands of slaty schist, with traces of dark schist or shale, apparently alternating in places with thin bands of greenstone.
3. Upper bed of greenstone, generally fine-grained and quite schistose in places, with some lenticular bands of agglomerate.
4. Bands of light coloured and dark chert, associated with bands of laminated black shale or schist, and a band of schistose grit.
5. Lower bed of greenstone, often massive—it contains an agglomerate band on the north side of the valley.
6. Bands of black shale or schist, associated with chert, and with some fine-grained slaty schist.
7. Thick mass of strong and coarse schistose grit, sometimes greenish and different in character from No. 1.

The whole succession may be observed in the North Sannox Burn, and on the hillside to the southward. On the north side of the valley, the upper grit and greenstone are at first almost entirely concealed by glacial drift, and eventually cut off by the Highland Border fault. In the lower part of the section, the gritty schists are well exposed in the stream, both above and below the bridge, where the road to Loch Ranza crosses. They are here traversed by a few basalt dykes. About 70 yards to the east of the bridge, the coarser rock contains an intercalated band of fine-grained schist, and 80 yards farther down the stream, dark schists are seen to be associated with a brecciated rock, the like of which is met with in several places. It is composed of fragments of greenstone, but is not exactly like a true volcanic agglomerate. It may possibly have been produced by the brecciation of igneous rock while still in motion before complete consolidation. Above these rocks in the main stream comes the lower greenstone (5 in Table), which occupies the burn for a hundred yards. It is for the most part a massive rock, moderately fine-grained and of greenish-grey colour. It exhibits a well-developed "pillow-structure," identical with that of the basic

North Glen
Sannox. (Mr.
W. Gunn.)

Arenig lavas of the Southern Uplands. The chilled and rounded margins of these "pillows," and the numerous amygdulæ, a short distance in from their surfaces, are marked features. The dark schist that apparently overlies the lower greenstone is much contorted in places, and is accompanied by a breccia similar to that just mentioned, and also by some bands of igneous material. The cherts which are associated with this black schist are well exposed, about 200 yards up the Allt Carn Bhain. Some of them are dark in colour, but the thickest bands seem generally to be light-coloured or grey. On the south side of the valley, the upper greenstone rests immediately on a strong gritty band; the former much resembles the lower bed, but with the "pillow" structure not so prominent. Its upper part is here and there so schistose that it might be taken for the so-called "green beds" of the Southern Highlands. A good exposure of the upper greenstone is to be seen on and about the two small hills called Cnocan Donna, where the doubtful Arenig rocks attain their highest point above the sea. On each of the knolls a band of true agglomerate is interbedded with the greenstone. These bands are lenticular, and are made up of angular fragments of fine-grained greenstone. Neither of them can be traced for more than 40 or 50 yards along the strike, and the more southerly is but five or six feet across at its widest part. The other is larger, and may be as much as 30 feet broad in one place. The upper schistose grits, only partly exposed in the main burn, form a prominent feature on the hillside 300 yards to the southward, and can be examined along the strike for a considerable distance in this direction till they in turn are cut off by the granite.

The lower greenstone forms prominent crags, one of which is a conspicuous object from the road, about 300 yards south-south-east from the bridge. The same sheet of rock is also conspicuous in the crags of Corloch, at the northern extremity of the strip, and it composes all the crags on the north side of the valley. There can be little doubt that these bands of greenstone are true lavas. They present many points of resemblance to the lavas of the Arenig volcanic series of Ayrshire.

At a distance of nearly 600 yards north from the main stream, and near the Allt Dornach, a rock which differs much in character from the lavas was the first igneous mass noticed in this part of the island, and was regarded as intrusive. This view has subsequently been corroborated by the results of petrographical examination. The rock, however, is probably nearly of the same date as the lavas. Only a few specimens of the rocks of this presumably Arenig band in Arran have yet been examined microscopically by MR. J. J. H. TEALL, who adds the following notes regarding them:—

"[8666.] Crocan-Donna, North Sannox. Fine-grained, greenish-grey massive rock, composed of minute prisms of nearly colourless hornblende, epidote, leucoxene after iron ores, quartz, and chlorite. This is evidently an altered basic igneous rock, a variety of epidiorite. [From the upper lava, No. 3 on the Table on p. 69.]

"[8667.] Torr na Lair Brice, North Sannox. A scoriaceous rock, the North Glen cavities of which have been filled with calcite. The main mass is formed Sannox. (Mr of microlitic felspar, chlorite, leucoxene, and carbonates. This, again, is W. Gunn.) an altered basic igneous rock. It differs from the above in containing recognisable felspar. It is closely allied to, but not identical with, the common forms of pillow-lavas. [This is the lower lava, No. 5 of the Table.]

"[8688.] Torr na Lair Brice, near Allt Tornach. Moderately coarse-grained rock composed of patches of fibrous hornblende, relics of original deep brown hornblende, chlorite, plagioclase, epidote, and leucoxene. The original rock was probably a hornblende-gabbro. It may be termed uralitic gabbro. I have little doubt that this rock is intrusive. [This is the rock found near the Allt Dornach and referred to above as probably intrusive.]

"[8669.] Allt Carn Bhain, North Sannox, 200 yards from foot of burn. Similar to the last, but more highly altered. Chlorite and carbonates abundant. [There is not sufficient evidence on the ground to decide whether this rock belongs to the lavas or is intrusive.]

"The two fine-grained rocks [8666 and 8667.] are highly altered basic 'traps' (greenstones) allied to those found in association with cherts in other areas. The two medium-grained rocks are altered gabbros or diabases [8668 and 8669]."

SILURIAN.

The chief field-work of the past year among Silurian formations has lain in the east and south of Ireland, where the revision described in previous *Summaries of Progress* has been continued. Much attention has necessarily been given to the igneous masses which in these regions are associated with the Silurian rocks. Hitherto a large proportion of these masses has been mapped as consisting of lavas and tuffs contemporaneous with the formation in which they are intercalated. But as the revision has advanced, an ever-increasing body of evidence has been accumulating to show that rocks which have been mapped as "ashes" are often of intrusive origin, while some of them are grits or arkoses.

Counties Dublin and Wicklow.

In resuming field-work to the south of Dublin, MESSRS. EGAN and McHENRY began by a study of the ground lying to the west of the great range of Leinster granite, where on the published maps a number of strips of "greenstone ash" are shown as intercalated among the Silurian strata. A careful examination of these rocks failed to disclose a single band of volcanic tuff, all the outcrops so represented on the map being either true felspathic grits or more or less crushed basic sills and dykes. Where the rocks have escaped deformation their true nature has generally been recognised, but the influence of terrestrial movements in inducing new parallel structures has only been recognised in recent years, so that it need not be matter of surprise that even portions of the Leinster granite were in some instances mapped as sedimentary material.

Among the principal localities at which ordinary sedimentary strata were mistaken for "ashes" may be mentioned the Deer-

District West
of the Leinster
Granite.
(Messrs.
Egan and
McHenry.)

District West
of the Lein-
ster Granite.
(Messrs.
Egan and
McHenry.)

park area west of Blessington, the river Liffey between Ballymore Eustace and Pollaphuca, and other places in the adjoining parts of the county Wicklow. Many other sections occur (Sheet 129), as, for example, in large quarries east of Dunlavin; also near Rathbran, west of Stratford, and in the country lying west and north-west of Baltinglass.

The crushed basic igneous rocks (in Sheet 129) were in all cases taken either for "greenstone ash" or, in the more intensely sheared portions, for Silurian sediments. Examples of both these identifications occur at Ballymooney, north of Donard; at Deerpark, south-south-west of Donard; and within the granite area at Colvinstown. Those at Ballymooney and Deerpark present features of special interest, seeing that some contain large crystals of felspar (Lambay porphyry type), while others pass gradually into amphibolite. The varied effects of the underground movements that gave rise to the deceptive appearance of bedding are well displayed there.

The results of his study of the microscopic structure of the grits and igneous rocks lying to the west of the Leinster granite has been prepared by MR. HENRY J. SEYMOUR, and will be found on p. 176.

In the portion of the county Wicklow west of the granite, acid igneous rocks do not occur. In the adjoining part of county Dublin, however, near Rathcoole (Sheet 111), dykes of felstone (mapped as "elvan") cut across the beds of slate. These resemble many of the felstones associated with the basic rocks east of the granite.

District East
of the Lein-
ster Granite.
(Messrs.
Egan and
McHenry.)

On the east side of the granite (in Sheets 120, 130, and 139) rocks which have hitherto been regarded as occurring in the form of contemporaneous "ash" have been found by MESSRS. EGAN and McHENRY to be either crushed igneous rocks or occasionally non-pyroclastic sediments. So far as these observations have yet gone, this correction has invariably had to be made. As the revision is carried southward in detail into the County Wexford, it remains to ascertain how far other areas really include contemporaneous "ashes." From a cursory examination it is surmised that true tuffs may possibly occur in the igneous area stretching south-west from Carrigadaggan* (north-west corner of Sheet 169) towards Waterford.

The oldest igneous rocks east of the granite are the basic varieties, which occur as ordinary diorites or as andesites. In Wicklow, examples are met with in the Bray Head railway-cutting, and at Greystones (Sheet 121). Southwards (Sheet 130) they exist a short distance south of Roundwood, and in the mountain overhanging the north side of the Upper Lake at Glendalough. Near Roundwood the rock is a variolite, slightly altered, the variety at Glendalough being partly amphibolite, and partly fine-grained diorite.

These rocks are largely developed in the south-east part of

* The name Carrigadaggan, which is not on the one-inch map, is that of a fossil locality, as published in the memoir of Sheet 169. It is a townland about seven miles east-south-east from New Ross.

Sheet 130, especially in the Avonmore River valley south of Rathdrum, and in the vicinity of Westaston and Kilmacrea Upper, about three miles east and south-east respectively of Rathdrum. They also form knobs in the hilly ground near the coast in the vicinity of Rockfield House and Brittas. Many minor dykes of diorite also occur along the coast southward from Wicklow Head.

District East
of the Leinster Granite.
(Messrs.
Egan and
McHenry.)

As a rule the true intrusive character of these basic rocks has been fairly recognised and expressed on the published maps; but where they have acquired a fissile structure from crushing and deformation they have been mistaken for sediments.

The microscopic characters of these rocks as developed near to, and at some distance from, the Leinster granite, have been studied by MR. SEYMOUR and will be found summarised on p. 176.

The acid rocks were less accurately treated by the older observers. Hence considerable modification of their mapping has been necessary. In all the cases hitherto examined the supposed "felstone ash" has been found to consist of crushed felstone of intrusive origin. Not only so, but in a large number of instances what have been regarded and mapped as interbedded sediments are really portions of true eruptive felsite, excessively crushed. Abundant evidence of both these conditions is found in the Kilmacoo mining district, south-south-east of Rathdrum (Sheet 130); also in the railway cuttings near that village, and along the river valley to the south. Fine sections occur on the coast at Ardmore Point; at The Castle: near Rockfield House; also in the Kilmacoo district just now mentioned. In many of these sections the rocks have a banded structure showing fine and coarse materials made up of broken felsites and pieces of sedimentary material. In some instances portions of pumice and lapilli have been detected by MR. SEYMOUR with the aid of the microscope, though the evidence on the ground indicates an intrusive origin. Instructive sections exist on the coast at Arklow Head, where many dykes of acid and basic rocks are exposed. The petrographical characters of the felsitic rocks of this region are discussed on pp. 179, 180.

An interesting and probably important point bearing on the age of the so-called "ashes" and acid "lavas" is the connection which MESSRS. EGAN and MCHENRY believe they have established between these rocks and the great granite ridge of Leinster. In many places masses which are mapped as "elvan," but are really granite, and some of which are acknowledged to be offshoots from the main granite mass, pass into the "felstones" and "ash," as at Lewis Vale, two miles north of Arklow, and at Rock Little, two miles south of that town. The same transition is seen on a larger scale in the Croghan Kinshelagh district south of Aughrim, where a granitic rock, mapped as "ash," graduates into felstone on the hill at Kilmacrea Upper, east-south-east of Rathdrum. The Leinster granite was intruded into the Silurian formations before the time of the Carboniferous Limestone, and is thus presumably of the age of the Old Red Sand-

District East
of the Lein-
ster Granite.
(Messrs.
Egan and
McHenry.)

stone. The sheets of "felstone" connected with it cannot therefore be "lavas" of Silurian date. In the Croghan Kinsbelagh district the shearing forces have affected the granite as well as the basic intrusions, and to such an extent that in many places the rock has actually been mapped as grey grits and slates.

One of the most novel features in the recent work of revision in Ireland has been the discovery of a number of cases of intrusive felsites, which present an internal finely brecciated structure so exactly simulating that of true volcanic tuffs that in hand specimens they would be unhesitatingly pronounced to be unquestionably of pyroclastic origin. The process by which they were produced is not yet satisfactorily explained, but this much may at least be asserted regarding them, that they form irregular eruptive bosses or dykes, and have been injected in veins and threads into the contiguous rocks. As far back as 1896* MR. McHENRY expressed an opinion that certain conglomerates in County Dublin, supposed to be of volcanic origin, had really been produced by intense crushing within the earth's crust, and at the same time he suggested that this might also have been the mode of formation of other masses in Wicklow and Wexford, which had always been looked upon as composed of truly volcanic detritus. During subsequent years this suggestion has been verified by the field-work of MESSRS. EGAN and McHENRY in County Wicklow, and also by the microscopic study of the rocks by MR. SEYMOUR. Remarkable sections of these brecciated felsites are to be seen at Arklow Head, where their intrusive nature is shown. They are displayed still more clearly on the shore near Rockfield House (Sheet 130) between Mizen Head and Wicklow Head. They have always been regarded as tuffs, and appear as such on the Survey maps. An account of their minute structure by MR. SEYMOUR will be found on p. 179. Similar rocks were met with by MR. KILROE on the south coast of County Waterford and will be referred to in subsequent pages (see pp. 77-81, and 180). It may be added that in no instance have MR. EGAN and MR. McHENRY succeeded in detecting any volcanic detritus in the sedimentary strata near the igneous rocks, whether the latter are crushed or not.

Counties Dublin, Meath, and Down.

Slane,
Bellewstown
and Balbriggan.
(Mr.
McHenry.)

In order to prepare for the engraver the maps of those parts of the East of Ireland of which the Silurian tracts have been revised, it was necessary to re-examine the igneous rocks of these districts that the nomenclature might be brought up to date. In the counties of Dublin and Meath, towards the end of the past season, MR. McHENRY re-visited some special points in the Slane, Bellewstown, and Balbriggan districts, and was accompanied by MR. SEYMOUR, with a view to the petrographical study of the rocks. MR. McHENRY has supplied the following notes

* *Nature*, March 6th, 1896.

of his re-examination. His recent work has confirmed him in the conclusions which he had formed in 1896, that the rocks which have hitherto been mapped as "ashes" in those districts are not of contemporaneous origin with the Silurian strata, but are really intrusive rocks, though in external and internal characters, closely resembling tufts and breccias. The igneous rocks and associated breccias and "ashes" that occur along the coast at Balbriggan, and to the west of it at Herbertstown, are, in his opinion, basic intrusive rocks of one period, but of many varieties. They must at least be later in age than the Upper Silurian strata, which they penetrate, and, like the similar masses in South Dublin, Wicklow, and Wexford, they may belong to the great volcanic and plutonic series of the time of the Old Red Sandstone. In the Bellewstown Hill and Ardcath areas, respectively five and seven miles south of Drogheda, both acid and basic varieties occur, the basic being similar to those at Balbriggan in their general characters and mode of occurrence, while the acid varieties closely resemble those of Wicklow and Wexford. Again, a mass of igneous rock at Craig Barron, west of Slane (Sheet 91), mapped as felstone, has been ascertained to be really of basic composition (dolerite, etc.).

Slane,
Bellewstown
and Balbrig-
gan. (Mr.
McHenry.)

To the west of Slane various acid masses, mapped as felstone and felstone ash, have hitherto been regarded as contemporaneous with Lower Silurian strata. As some of them, however, are distinctly intrusive in the fossiliferous Upper Silurian series, they cannot be of Lower Silurian age, but from their very close resemblance in every respect to the Wicklow and Wexford types they not improbably belong to the same late period.

The two long east and west masses of rock mapped as "felstone" at Grangegeeth, three miles north of Slane, are now determined not to be igneous at all, but merely an arkose, composed of broken-up and disintegrated felspathic detritus in a fine green sandy matrix, which contains fossils in places.

In County Down a similar re-examination was undertaken by MR. EGAN of the abundant intrusions of igneous rock along the shore to the north of the mouth of Strangford Lough. He was accompanied by MR. SEYMOUR, whose notes on the petrographical results of the examination will be found on p. 180.

Co. Down.
(Mr. Egan
and Mr.
Seymour.)

County Waterford.

The revision of the Silurian ground in the County of Waterford has been continued during last season by MR. KILROE, who has prolonged to its southern limit the line of boundary between the Lower and Upper Silurian formations. In this mapping the available evidence was entirely lithological as far as Kilmeadan, four miles west from Waterford, the strata proving barren of organic remains until, near that place in the railway cutting at Mount Congreve, they were found by the Fossil

Co. Water-
ford. (Mr.
J. R. Kilroe.)

Co. Water-
ford. (Mr.
J. R. Kilroe.)

Collector, MR. R. CLARK, to contain double graptolites, probably indicative of Bala or Caradoc age. The boundary is crossed obliquely by bands of felsite, which, being highly cleaved, were represented as slate and grit on the published maps.

Caradoc strata in great variety, interspersed with igneous bands, are to be seen throughout the southern part of the County of Waterford (Sheets 178 and 179). They extend to the coastline, and pass beneath the Old Red Sandstone of the Comeragh Mountains on the west, and of Dunmore and Brownstown Head on the east. Near the Upper Silurian area the strata consist of rapidly alternating grey grit and dark grey slate bands.

Similar slate and grit in larger bands are common further south; and black slate, containing, as at Garrarus, Caradoc trilobites, appears in many places. Green grits and epidotic slates, frequently calcareous and fossiliferous, occur in small isolated areas surrounded by igneous rocks in a triangular tract, which extends from Ballynamona southward to the coast and westward towards Durrow. These rocks have peculiar interest, as they are associated with the only true, scantily-represented volcanic tuffs that MR. KILROE has been able to detect in the region. The Bala or Caradoc strata also contain red grits, which are seen in a stream two miles west of Tramore, and associated with green grit and tuff at Sheep Island and at Knockmahon. Earthy limestones and calcareous grits rise into cliffs some 80 feet high at Dunabrattin, and 100 feet near Tramore, this group of strata attaining a visible thickness of 400 feet at the former place, and 650 feet at the latter. It appears also at Green Island near Annewstown, and at several other points along the coast. The prevalence of Bala fossils at Tramore and Dunabrattin has long been considered to fix the stratigraphical horizon of these limestones; and it is doubtful whether the interesting occurrence of Russian and Scandinavian Llandeilo forms, recently pointed out by MR. COWPER REED,* should be accepted as subversive of the conclusion.† The section seen at Carrigaghalla referred to later on, which MR. REED gives as corroborative of his opinion, is of very doubtful value, having regard to the great disturbances which have affected the region.

Black slate, which appears from beneath the limestone near Tramore and at Dunabrattin, may on account of its position, on lithological grounds and in the absence of fossil evidence, be assumed to be of Llandeilo age, like the black slates so distinctive of the Llandeilo formation all over Ireland. Similar black slate found in many other places in the district may in some cases be of the same age; in others, however, it belongs to a Bala

* *Quart. Journ. Geol. Soc.*, vol. lv., p. 766.

† Especially in the absence of such forms from the Llandeilo limestone of Wales—a difficulty which the author admits. If the existence of these forms near Tramore be the result of migration westward, it would be reasonable to assume that they reached the Waterford area at a later epoch than the Llandeilo. Instances bearing out the presumption have been indicated by MR. MARR, and are referred to in MR. C. REED's Paper, page 770.

horizon, as is shown by its fossils. The relation of the black strata to the limestone is rarely manifest.

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MR. COWPER REED reports the occurrence of *Dicranograptus* in black slate, which, dipping at an angle of about 80° , at present overlies limestone at Carrigaghalla, 450 yards south of the boat pier at Lady Elizabeth's Cove, near Tramore. In order fully to appreciate the bearing of this section it should be noticed that a continuous series of limestones and grits, visible in Newtown Cove, half a mile to the north of Great Newtown Head, runs inland for about 250 yards, and that the strike of these strata is fairly regular along the cliffs northward. A corresponding succession of limestones and grits might be expected to appear at Carrigaghalla, forming the cliff, and probably also proceeding inland. Instead of this development, however, the limestone is only seen at the base of the cliff, the cliff itself being formed of igneous rocks and the black slate, which is faulted. A thin felsite-sill and a massive basic one separate the limestone from the slate above, the slate being further penetrated by felsite higher up in the cliff, which is here crowned by another basic sill. The structure, therefore, is not regular and normal, so that any conclusion based upon the present position of the slate, relatively to the limestone, can hardly be well founded. The *Dicranograptus* slate would otherwise have to be taken to represent the fossiliferous calcareous grits of the glen at Newtown Cove, where no black slate occurs. The black slate at Carrigaghalla may be considered as in all probability a detached mass, caught in a group of igneous intrusions and carried upward out of its natural stratigraphical position. This view of its relations finds ample illustration in sections along the coast from Newtown Head westward, where similar detached masses of sedimentary rocks are to be seen, surrounded by igneous rocks.

IGNEOUS ROCKS OF THE WATERFORD COAST.

The igneous rocks of the County of Waterford have long attracted attention. Their varieties of composition, structure, and mode of occurrence have been noted, as well as the difficult problems which these varieties present to the geologist. Some notes on the petrography of these rocks by MR. SEYMOUR will be found on p. 180. The following petrographical types have been recognised in the field by MR. KILROE.

(1.) The oldest of the whole series appear to be light and dark-green andesites and other more basic rocks, such as diorites and diabases. The andesites are usually epidotic, and sometimes porphyritic, with crystals of augite.

(2.) Volcanic tuffs associated with Silurian grits, seen at Sheep Island, and other points along the coast. The contained fragments consist chiefly of felsite, sometimes perlitic, glassy or highly vesicular, with pieces of andesite and other more basic rocks and fragments of black shale.

(3.) Compact light-grey and pink potash-felsites, frequently vitreous and showing flow-structure, occasionally containing detached pieces of lime-

Co. Waterford. (Mr. J. R. Kilroe.) stone as in the sea-stack west of Sheep Island. At this point of the coast, the pink felsite is seen to break into a "breccia" which belongs to the next series.

(4.) Breccias—forming, for the most part, the coast between Great Newtown Head and Annestown, described on the published map in certain places as "felspathic ash" and "greenstone ash" and more recently regarded as "volcanic agglomerates." They are, however, intrusive rocks as will be more fully explained a little further on.

(5.) Green plagioclase-felsites, passing into andesites, and in certain places into "diorites." These prevail in the western part of the district, while the foregoing group predominates in the eastern. Similar rocks, however, form great dykes and sills to the east of Annestown, and may be seen along the coast as far as Great Newtown Head. At Sheep Island, offshoots from the dark green felsite of this group penetrate the breccia of Group 4, and massive sills of the same material invade and include between them an important lenticular band of strata consisting of fine tuff and green and red grit, the tuff graduating upward into the grit. The lower part of the upper sill displays a remarkably well-developed spherulitic structure in a band several feet thick on the south end of the island.

These green rocks—felsites, andesites, &c.—frequently assume a fragmental form like those of the previous group which are grey. They contain pieces of felsite of various kinds from small chips up to large blocks. In one remarkable instance, a little to the west of Ballydowane Bay, a sill consisting almost wholly of partially-rounded masses (the matrix being very scanty), includes some blocks more than two feet in diameter. Many of the lenticular bands in this group are cleaved, which no doubt led to their being mistaken for "greenstone ash."

(6.) Grey potash-felsite, usually porphyritic, which occurs in massive sills near Tramore and is recognisable along the coast to Ballyvoyle Head, near Dungarvan. It is probable that grey granite, similar to that of the Wicklow range, which occurs in lenticular areas trending south-westward, belongs to this stage of intrusion, inasmuch as one of the areas, north of Ballydowane Bay, seems continuous with that of a grey porphyritic felsite seen on the roadside near that bay. To this stage also belongs a striking porphyritic felsite with red felspar embedded in a green matrix, which occurs in two localities, north-east and south-west from Stradbally. Prismatic, spherulitic, and perlitic structures are occasionally to be seen among these felsites.

Green epidotic grits and fossiliferous slate of Bala age are seen to overlie the andesites of Group 1 north of Ballyscanlon Lough; while conglomerates, which form the base of the sedimentary series here and at Munmahoge, nearly three miles north-by-west of Tramore, contain pebbles almost wholly derived from similar andesitic rocks. It is, therefore, obvious that the Ballyscanlon andesites are more ancient than a portion of the Bala group, though there is no evidence that they were erupted contemporaneously with that group. No such satisfactory evidence of stratigraphical position is available for the determination of the age of the other andesites of the district; for while rocks closely resembling those of Ballyscanlon are to be seen in many places, they may be suspected to be of later date than the green Silurian strata. Some masses, however, to the west of Ballyscanlon, such as those of Corrig Castle Hill, near Ballylannan, are at least older than the brecciated felsites of Group 4.

The tufts forming Group 2 have been found in widely scattered patches, none of which perhaps exceed a few hundred square yards in area. They seem to be everywhere surrounded by later felsites.

Of the section at Sheep Island, the Director-General, who inspected the ground last summer with MR. KILROE, has fur-

nished the following notes:—"A mass of pinkish-grey felsite rising out of the sea is surmounted by about 18 to 20 feet of well-bedded alternations of a fine breccia and of thin green shaly layers. The fragments enclosed in the breccia consist of small chips of highly vesicular felsites, andesites, and probably some more basic rocks. These materials are obviously of igneous origin. The most abundant of them are lapilli of a fine dull-green extremely minutely cellular pumice, which recalls the familiar basic lapilli of the Carboniferous tuffs of the basin of the Forth. They include also fragments of pink felsite with exquisitely perfect flow-structure. Many of the strata of this breccia are coarser at the bottom and become finer towards the top. There can hardly be any doubt that these strata are true tuffs. They pass upward at one place into some red shales and grits, the bedding of which is parallel with that of the tuffs below.

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"Above this fragmental band comes another felsite, which is particularly conspicuous for the great perfection and beauty of its spherulitic and flow-structures. These structures are grouped parallel with the under surface of the sheet. The lower band of the rock is remarkably spherulitic. Some of the spherulites, composed of a very flinty pink felsite, measure three inches in length and many of them enclose a nucleus. Higher up in the sill bands of fine spherulitic material may be observed, the spherulites being small and round like peas, and scattered sparingly through the matrix. The lower portion of this felsite is traversed by a dyke two feet six inches broad, of a grey compact finely vesicular felsite."

The most important part of MR. KILROE'S revision of the igneous rocks associated with the Silurian formations of the south of the County of Waterford has reference to the remarkable brecciated masses of that region. As in Wicklow and Wexford, these rocks have hitherto been considered as tuffs and agglomerates, but close re-examination of the remarkable coast-sections where the rocks are so well exposed, has led MR. KILROE to the same conclusion as his colleagues—MESSRS. EGAN and MCHENRY (*ante* p. 72). He believes that the main mass of the igneous rocks is of intrusive origin, and that most of the so-called agglomerates and breccias are not truly volcanic masses, but have been produced by a process of brecciation during the prolonged period of igneous intrusion. At the same time the microscopic study of the rocks by MR. SEYMOUR has shown that some of them are true felsitic tuffs, with glassy and vesicular lapilli.

The fragments enclosed in these "intrusive breccias," to use the term originally employed by MR. MCHENRY, consist principally of various felsites and other igneous rocks, but include also, sometimes abundantly, angular pieces of black slate and grit, derived from the surrounding Silurian formations. The felsite fragments often show flow-structure, and have obviously been derived from a rock such as that which may here and there be seen in veins and sills traversing both the igneous

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and sedimentary masses of the coast-cliffs. Some specially instructive sections showing the character and relations of these rocks may be seen at Sheep Island, two miles west of Great Newtown Head, and on the adjacent part of the shore. Here the observer may follow, as it were, the successive stages in the process of the production of the brecciated structure in an intrusive molten rock. The original felsite has been broken up, and its fragments have been carried forward in a fresh inroad of similar material. The newer matrix sends veins into the included fragments, as may be well seen where the pale greenish grey felsite traverses a block of black slate. In some places, as at St. Ronan's Bay, south of Tramore, the quantity of included fragments sometimes amounts to about three-fourths of the whole mass, only one-fourth part being the matrix in which they are enveloped. It is difficult to realize how an intrusive rock so charged with foreign material could have been injected into cracks and fissures of the crust.

That this breccia moved as such, and was forced into irregular apertures or rents in previously solidified rocks is well displayed at many points of the coast-line. A remarkable section occurs on the cliff immediately behind Sheep Island, of which the Director-General has supplied the accompanying figure and notes :—

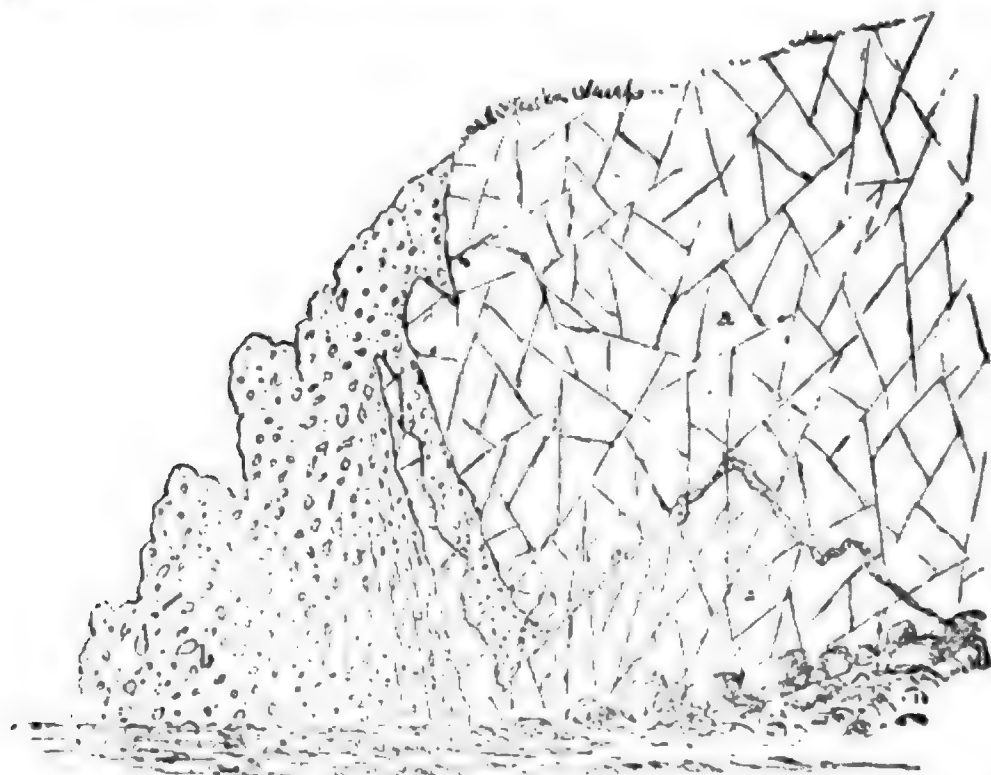


FIG. 1.—Section of Intrusive Breccia (*b*) in Felsite (*a*), shore opposite Sheep Island, south of Tramore, Co. Waterford.

“The older rock (*a*) of this section is one of the usual pinkish felsites which have so abundantly invaded the igneous and sedimentary masses of this coast. The younger rock (*b*) is a green ‘breccia’ of the prevailing type, but with a less proportion of included stones than may often be seen in other similar masses. The fragments which, however, are sufficiently numerous, consist largely of felsites, some having a beautiful flow-

structure and others showing a vesicular texture. They include also pieces of a reddish limestone. It will be observed from the figure here given (Fig. 1) that this breccia is intrusive in the felsite. It sends a long dyke or vein downward in the latter rock, of which it thus separates a strip at the margin. A little above the beach this dyke or vein bends sharply upward and rapidly lessens in thickness, but continues in a sinuous course through the felsite until it dies off in a narrow finger or thread. From the sharp bend just mentioned to the extreme end of the vein is a distance of seventeen feet. In the thicker dyke or vein to the left, the size of the stones is less than in the body of the breccia, and these are still smaller in the attenuated vein that strikes off to the right. But they continue to be present even up to the end.

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"The matrix is a fine felsite, about the true origin of which as a molten rock there could be no doubt if it were considered in itself and apart from the problem presented by its included stones. It has been obviously intruded here into an irregular rent, and its load of fragments has been as it were strained off by the narrowing of the passage until only fine chips were borne along to the end."

Petrographical notes on some of these interesting rocks have been prepared by MR. SEYMOUR, and will be found on pp. 179, 180.

If the majority of the igneous rocks of the Waterford coast, hitherto regarded as volcanic sheets intercalated contemporaneously among the Lower Silurian sediments, are now to be regarded as really intrusive in, and therefore later than these formations, the important questions remain of (1st) the geological era to which the prolonged injection of this enormous series of eruptive masses is to be assigned, and (2nd) the stratigraphical relations and age of the volcanic eruptions represented by the tufts. As the intrusions have invaded all parts of the Lower Silurian series of the district, they are clearly of later date than these. North of Kilmaethomas MR. KILROE has found cleaved felsites closely adjacent to Upper Silurian strata. The sections are not conclusive as to the relations of the two groups of rock, but if the felsite is not brought in by faulting or folding but is really intrusive in the surrounding strata, it will follow that some at least of the protrusions cannot be older than some part of the Upper Silurian period. But the date may be more nearly defined by the evidence of the coast-line at Ballydowane Bay to which fuller reference will be made in the account of last year's field-work in the Old Red Sandstone (*postea*, p. 101). It will be shown that there is a high probability that the igneous protrusions of County Waterford belong to that remarkable period of hypogene and volcanic activity which witnessed the injection of so many of the chief granitic masses of the British Isles and the outpouring of such vast sheets of andesitic lavas and volcanic agglomerates and tufts.

Island of Arran.

An account of MR. GUNN's interesting discovery of another exposure of the cherts and black schists on the Highland border has been already given in the section on the Dalradian rocks (*ante*, p. 68). But as these strata may with the highest probability be relegated to the Silurian system, a brief allusion to them again may not be inappropriate at the end of the foregoing narrative of recent progress among the Silurian formations of Ireland. MR. GUNN, in his report of his year's work, justifiably stated that the most important addition to the geology of Arran is the discovery in North Glen Sannox of a volcanic series associated with the schistose grits of that region. This set of lavas occurs in connection with volcanic agglomerate, with cherts and with dark shales or schists, like the rocks of Ballantrae in Ayrshire, and the whole is probably of Arenig age. No organisms have yet been discovered, however, either in the cherts or in the dark schists, but it is to be hoped that when the rocks come to be thoroughly searched by the fossil collectors, organisms will yet be found. Great interest attaches to the rocks in this area because they appear to be intercalated in the Highland schists, the whole forming apparently a regular and conformable succession. By this discovery the number of distinct volcanic series in Arran is increased to six.

These igneous rocks were first noticed in the month of June, but very little was then done in working out their relations to the associated schists. Specimens, however, were obtained of several varieties of the rock, and on these being shown to MESSRS. PEACH and HORNE, they at once remarked on their resemblance to the lavas of Arenig age near Ballantrae. It was not till late in the year that the survey of the district was resumed, and the area occupied by these volcanic rocks was mapped in detail. After this was done MR. PEACH spent a day on the ground with MR. GUNN, seeing most of the principal sections, and he had no hesitation in identifying these rocks with those of Arenig age at Ballantrae.

As has been already pointed out, no structural line of separation can be detected between these presumably Lower Silurian rocks and the ordinary Highland schistose grits between which they are intercalated. The question is thus again raised as to how far the Silurian age of the rocks is to be extended into the Highlands. It has been impossible to find any lithological difference in the condition of the strata that are almost certainly Arenig, and the schistose grits alongside of them. They have undergone the same plication and the same degree of metamorphism, and they undoubtedly seem to form parts of one continuous and unbroken series. We are not yet in a position to solve this difficult problem. But important data are accumulating for its solution. There now seems to be every probability that both Lower Silurian and Cambrian formations enter largely into the composition of the great mass of the Highland schists.

DEVONIAN.

Cornwall.

The field-work of the Survey among Devonian rocks last year has been confined to the County of Cornwall, where it has been carried on in the Eastern border by MR. USSHER, in the Falmouth district by MR. HILL, and around Penzance and the Land's End by MR. WILKINSON.

MR. USSHER has mapped Upper, Middle, and Lower Devonian rocks in the districts of Liskeard and Looe (Sheet 348). The larger part of the area surveyed consists of Lower Devonian rocks. These make a natural junction with the Middle Devonian slates south of Liskeard, but are cut off against Upper and Middle Devonian slates with volcanic rocks on the east by a fault that runs in a south-easterly direction from the vicinity of Clicker Tor near Menheniot Station. By this dislocation and others parallel to it near Mount Edgecumbe, the Lower Devonian outcrop has been shifted to more northerly positions.

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The Lower Devonian rocks are greatly disturbed by numerous contortions, thrusts, and faults, which obscure the relations of the divisions at crucial points. Their uppermost strata consist of sandstones with argillaceous slates and shales (developed south of St. Keyne), which seem to be practically unfossiliferous, and are usually of a dull greenish and grey colour. Owing to repetition by plications they exhibit a greater development on the west than on the east of the East Looe river. They are succeeded by grey slates, occasionally siliceous, and with local beds of hard grit. Thus far the Lower Devonian succession is perfectly clear, but beyond this point it is obscured by the manner in which the remaining components of the series are distributed. These embrace the Looe beds and the Polperro beds.

The fossils recorded from the Looe grits and shales are said to characterise the "Gedinnian" group of the Continent, that is to say, they indicate a lower fauna than any other found in Devonshire. The rocks with which the organisms are immediately associated include limestone in no persistent quantity, but in character, and seemingly in fossil contents, identical with beds in the Plymouth section. They comprise also interlaminated beds similar to those of Torcross and Tinsey Head. These are well shown in the coast-sections. The calcareous bands seem to occur at different horizons, but are most apparent near to or actually in contact with the red or buff shales and grits of the Looe beds. The slate series, although to a great extent identical in character with the slates which succeed the St. Keyne sandstones, is more variable, containing irregular grits, compact grits, and fossiliferous partly siliceous, irregularly cleaved grey slates, closely similar to characteristic types of the Meadfoot beds of Torquay. This similarity is so strong that were it not for their Gedinnian fossils the Looe grits and shales might well be regarded as a part of the Meadfoot beds (Lower Coblenzian) with distinctive,

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locally recurrent, but impersistent lithological and paleontological characters. The classic fish-beds of Polperro lie among dark slates and hard grits, which are no doubt a part of the slate series that includes the Looe beds, but the distribution of the organisms is more general in the purple green and buff slate series of Polperro, Talland and Dowerry. These variegated strata are precisely like the Dartmouth and Kingswear slates and also the slates and grits of the Revelstoke and Wembury shores. At Piskeys Cove on the Revelstoke coast MR. USSHER found remains of *Pteraspis*. Although a boundary has not been continuously drawn for the Dartmouth slates in Devonshire, their persistence and identity with the variegated slates of Polperro has been clearly proved. The Dartmouth slates of Polperro, although faulted on the north, are shown in places in unfaulted junction with the dark slates which contain traces of fish. As far as can be judged from the evidence the calcareous beds in contact with the Looe grits and shales give place to these dark slates. The latter comprise intercalated beds of hard grit or quartzite which, where present, often show intense plication. These slates form the coast-section for five miles westward from Portwrinkle, where they are faulted against Looe beds. The dislocation at first escaped notice, the red beds of the Looe series between Craithole and Cawsand having been very naturally confounded with those of the Dartmouth slates. In the Seaton River Valley, below Hessenford, the grey slate series, with its associated grits and calcareous bands and patches of Looe beds, presents many points of resemblance to the strata above the slates of the Kingswear promontory which correspond to the Meadfoot beds of Torquay. These grey slates, which are the inland continuation of those in the East Looe coast, are bounded on the south by the Dartmouth slates of the Dowerry coast, the boundary being in part at least a fault, and on the north by a mass of the Dartmouth slates which north of Hessenford extends over the ridge of Bindown to the East Looe River Valley. This mass is shifted by a fault between Bindown and Congorlan. On Bindown and above Congorlan very tough grits, containing *Pteraspis* remains, are present in association with quartzite and grey slates. On the north border of this mass, at Wringworthy, a small patch of Looe grits occurs, but with this exception there is no proof of the representation of the Looe beds in the slates on the north which come directly below the St. Keyne sandstones. In the district west of the East Looe River, the Dartmouth slates may occur in small patches. Grits resembling those above Congorlan have been detected, which may owe their position either to a prolongation of an anticlinal axis from Bindown and Congorlan, or to a fault. The slates under the St. Keyne sandstone may perhaps form the upper part of a great series, in the middle or lower part of which the Looe grits and shales and calcareous beds occur, and the dark slates, with fish remains and quartzite beds, may lie at the base of this series, directly above the Dartmouth slate group.

The chief problem of the geological structure of the Looe district

is centred in the mass of Bindown and Congorlan. This mass is most probably an anticline. If it be regarded as a single outcrop the almost entire absence of Dartmouth slates on the west of the East Looe River will have to be accounted for by faults cutting out the whole of these slates, a view which would place the Looe beds below the Dartmouth slates, and would well accord with their presumed Gedinnian age. The evidence as to the Lower Devonian succession afforded by the Looe district alone must be confessed to be quite inconclusive. Taken in connection with the data derived from previous Lower Devonian exploration, the balance of evidence inclines MR. USSHER to the simpler view that the downward succession is as follows:—

Staddon grits	-	St. Keyne sandstones.	
		Beeson, Churchstow and Grey slates, with occasional grit	
		Ringmore beds	- Looe grits and shales.
		Torcross and Tinsey Grey slates, with limestone and	
Meadfoot Beds		Head beds.	grits.
			Dark-grey slates, with inter-
			laminated beds, and quartzite
			bands.
Dartmouth slates		Revelstoke Beds	- Purple, green, and buff slates,
			with quartzite or compact
			grits and arenaceous beds.

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South of Pelynt the direction of dip of the schistosity is nearly always northward. The change in the prevalent southerly dip of this structure takes place along an irregular line drawn from the fault in Portnoller Bay toward Pelynt, which has no connection with any particular geological horizon. DE LA BECHE alludes to the rounding of the strike near Pelynt.

The Middle and Upper Devonian rocks in the district recently surveyed consist of slates and slaty mudstones, in which volcanic rocks occur. Their lower portions comprise argillaceous slates or slaty mudstones, often splitting prismatically, and with cleavage planes that dip generally at low angles, the bedding being frequently shown by vertically undulating, suture-like lines. Calcareous slates may be seen in the new railway line south of Liskeard Station, but there is no persistent limestone. The irregular distribution of the volcanic rocks in the tract of slate seems to be due to their lying in troughs of the higher Middle Devonian slates, and also to the fault-boundary of the Lower Devonian rocks, which cuts off the Middle and Upper Devonian series on the west, and is probably prolonged in the Middle Devonian area toward Liskeard. No boundary can be even approximately drawn between the Upper and Middle Devonian groups. Purple and green slates of the Upper group occur at Menheniot, and *Entomostraca* were obtained from them near Doddy Cross and Padderbury.

The Middle and Upper Devonian volcanic rocks consist of schalsteins and brown and greenish vesicular rocks, of which a good example is afforded by the mass on Padderbury Top. The Clicker Tor "Serpentine" is an ophitic dolerite, probably intrusive. A coarse-grained, probably intrusive basic rock occurs near Cartuther, and in the valley between that place and Menheniot.

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In the Lower Devonian area igneous rocks occur in many places but so sparingly developed and so decomposed that they cannot be indicated on the map without exaggeration. Although in places resembling sheared tuffs, their true origin remains uncertain. They are most frequently to be met with in the calcareous parts of the grey slate series associated with the Looe beds, but they also occur in the Dartmouth slates. Sheared diabases have likewise been found. The most interesting igneous rock yet encountered in the district is a highly silicified trachyte or andesite, which is quarried for road-metal on the southern slope of Bindown. It runs in an east and west direction, and is of small superficial extent. MR. TEALL has furnished the following notes regarding it:—

"[E. 3254 and 3255.] Bindown, S.S.W. of Menheniot. Grey or bluish-grey, highly quartzose rocks, traversed by veins of quartz and pyrite. Under the microscope they are seen to be highly silicified vesicular igneous rocks. Quartz has been deposited not only in the veins but also in the vesicles. The greater part of the rock is composed of quartz, but a certain amount of altered igneous material occurs as a matrix between the amygdaloids. This consists of a few rare phenocrysts of felspar in a groundmass of felspar-microlites and ill-defined interstitial matter. The nature of the original rock cannot be determined with certainty from these specimens. It appears to have been either an andesite or trachyte—most probably the latter."

Penzance
District.
(Mr. S. B.
Wilkinson.)

In continuation of his previous mapping, MR. WILKINSON has surveyed the tract lying to the north-west and south-west of the town of Penzance. The district is almost entirely occupied by granite, but sedimentary rocks, highly altered and traversed by masses of "greenstone," rise on its eastern margin. The boundary-line between the two groups of rocks is well defined on the coast at the fishing village of Mousehole, whence it runs inland and then circles round behind Madron and Gulval. On the coast at Mousehole the sedimentary series has been very much altered. The granite is there seen to have been intruded into bluish, flaggy, fine-grained strata, which it has baked and altered almost into hornfels. Nowhere else along the inland boundary has the actual contact of this intrusive mass been observed, but the sedimentary rocks, which are cleaved red shales, all show evidence of alteration. A large band of "greenstone" stretches from Mousehole to Newlyn among the sedimentary rocks which are there changed into hard and compact hornfels. Close examination of them indicates that they have been much puckered and plicated, and that they suffered their chief metamorphism, together with the "greenstone" mass, during the period of the granite intrusion. No evidence has been obtained as to the age of these sedimentary rocks.

The best-known mass of "greenstone" in this district is that which extends from Mousehole to Newlyn. It is much used for road-metal and for the manufacture of artificial pavement. At the Penlee quarries, which give employment to a large number of men, the rock is blasted out of the face of the quarry and is afterwards broken up by the hand and by machinery. It is an exceedingly hard and tough material, and on that account

cannot be worked with tools for building purposes. What is probably a continuation of this mass crosses the stream at Newlyn and crops out behind the church and at Mount Misery, extending in a northerly direction to Castle Horneck and Rosehill. The town of Penzance appears to have been built on a mass of this rock, which crops out at Lescudjack Hill and Coombe Quarry, extending in an easterly direction towards Gulval. In all these masses an extreme toughness of character is maintained. A large quantity of the rock is used locally for road-metal under the name of *blue elvan*.

Penzance
District.
(Mr. S. B.
Wilkinson.)

The granite of the Land's End district is seen to great advantage round the coast from Mousehole to the Land's End and thence northwards. In the interior the rock is not well exposed owing to the readiness with which it weathers and crumbles away, while round the coast, the weathering of the material along the joints gives rise to singularly artificial-looking masses. Inland the same kind of weathering occurs, but the rock appears there on the hill-tops in the form of huge mushroom-shaped bosses. Along one set of nearly horizontal or gently undulating joints the rock decays more readily than on the flat or rounded surfaces. Another set of joints which has a more or less vertical direction has not the same importance in determining the architectural aspect of the rock, but is effective in allowing it to weather into columns and obelisks.

The granite is a porphyritic rock, its most conspicuous constituents being crystals of grey felspar, which possess a beautiful pearly lustre, and are often three to four inches long and more than an inch in breadth. The ground mass through which the crystals are dispersed consists of quartz, felspar, and mica. Schorl also occurs at Castle Treneen, where the Logan Rock stands, and which is cited by DE LA BECHE as a good example of the occurrence of this mineral.

This beautiful granite is worked in several quarries. It is dressed on the spot, and sent away sometimes in enormous blocks. Besides the contact junction of the granite with the sedimentary rocks at Mousehole, already referred to, another is exposed further round the coast to the west at Tater-du-Point.

At Mousehole the granite penetrates and alters the sedimentary rocks into which it sends veins and tongues in every direction, and encloses portions of them. It is noticeable that the crystals of felspar (several inches long) are as large at the contact as they are in the interior of the mass. No "chilled edge" is here to be seen. On the other hand at Tater-du-Point, where the granite surrounds an inlier of "greenstone," it becomes gradually finer in grain for some six to eight yards from the contact, and at the actual junction presents a good example of the close texture so usual where masses of eruptive material have been rapidly cooled by coming against older and much colder rocks.

Veins of fine-grained granite have been observed at several places. At Mousehole fine-grained granite-veins pierce both the coarse porphyritic mass and the sedimentary rocks, while at Tater-du-Point similar veins cut across the main granite, and

also the "greenstone." At Whitesand Bay innumerable veins of granite, very fine in texture, and varying from an inch to several feet in thickness, cut the coarse porphyritic mass in every direction.

Falmouth
District.
(Mr. J. B.
Hill.)

Though there is reason to suspect that the rocks in the Falmouth district, long recognised to be Lower Silurian, are not by any means the only representatives of that system in this part of Cornwall, and that eventually it may prove that there are really no Devonian strata there, an account of the recent work of the Geological Survey in that district is inserted in the present section of this volume, in accordance with the order followed in previous *Reports*. Further research may justify the definite relegation of a considerable tract of ground in the south-west of the county to Silurian formations.

While the occurrence of Lower Silurian strata on the southern coast of Cornwall has been well known for so many years, the relations of these strata to the rest of the "killas" or "grauwacke" of that part of the country have never yet been ascertained. The structure of the ground is exceedingly complicated and can probably only be unravelled by patient examination with the aid of large-scale maps. This is the task which has been assigned to MR. HILL, who, from his station at Falmouth, has continued the Survey, of which some account was given in *last Summary of Progress*. He has made a perceptible advance during the past year, as will be seen from the following narrative which he has furnished:—

The field-work has been carried well into the interior. The various estuaries which diverge from Falmouth Harbour and the Helford river penetrate deep into the heart of the country, and afford more or less continuous sections of the strata. Their courses are so tortuous that the examination of them has involved the mapping of 68 miles of coast sections in addition to what was reported for 1898. These deep indentations have allowed the strata to be continuously followed without a break from the sea-coast at Falmouth to practically midway across the breadth of Cornwall. Advantage has also been taken of the numerous cuttings along the line of the Great Western Railway. All these natural and artificial sections have been mapped in detail, and have been of considerable service in the working-out of the stratigraphy of the district, since generally over the surface of the interior the rocks are only to be seen in isolated exposures and usually in an advanced state of decomposition.

It was mentioned in *last Summary* that, in the absence of paleontological data MR. HILL had separated the slates of the district lithologically into the following divisions * :—

1. Varyan beds.
2. Portseatho slates.
3. Variegated (Falmouth) slates.
4. Mylor series.

* *Summary of Progress* for 1898, p. 97.

These groups succeed one another in the order here given from east to west, and their persistence over wide areas as distinct stratigraphical horizons has been confirmed by the work of last year. The eastward extensions of the Portscatho slates in Veryan Bay were coloured by DE LA BECHE as Lower Silurian, and the same strata, after striking into Gerrans Bay, make their appearance again south of the Helford River. The part of the district to the south of Falmouth has now been examined, and the results of the work will here be briefly stated.

Falmouth District.
(Mr. J. B. Hill.)

In order to determine the relations between the Portscatho slates (No. 2) and the strata south of Helford River the coast-section was examined in detail between Falmouth Bay and the Nare Point. From Maen Porth, where the Variegated Slates (No. 3) are last seen, the coast, as far as the Helford River, presents an uninterrupted section of the blue slates and fine sandy beds of the Portscatho slate series in their normal condition. South of the Helford River they are well exposed as far as St. Anthony Creek. As they are followed southward, however, they have suffered more severely from the stresses which have induced the folding and cleavage of the rocks. At Dennis Head the structures set up by these movements have been carried a step further. The strata have been, as it were, subjected to mylonisation (or crushing) of a coarse type, inasmuch that they have been reduced to a mass of coarse lenticular patches of rock, the lenticles being several feet, in some cases yards, across, and the whole presenting the character of a gigantic breccia. These lenticles, when they have been torn from quartzose beds, resemble huge boulders; in other places the apex of a folded limb has been detached and isolated from the parent mass. This extremely coarse type of brecciated structure is more or less continuous along the coast as far as Porthalla, where the northern edge of the Lizard "complex" appears.

Between Dennis Head and the Nare Point a conglomerate is interbedded with blue slates. Near the Nare Head a quartzite appears, and further south, nearer Porthalla, a small limestone band. The limestone and quartzite, as well as the conglomerate, are found associated with the blue slates.

The conglomerate was described by DE LA BECHE,* who recognised in it fragments of hornblende-slate in addition to the material supplied from local sources. It is well seen on the shore east of Men-aver Point where it has an outcrop of nearly a third of a mile. Still farther east, at the Nare Point, conglomerate is again exposed for a few yards. As the strata are highly folded it is probable that the successive outcrops are parts of the same mass. Before the main body of the conglomerate comes on, thin seams of fine conglomerate may be observed to be intercalated in the slates. These seams vary from six inches to a foot in thickness. Commencing next the slates as sandstone, they rapidly become coarser, occasionally including fragments three or four inches across. The fragments are made up of black slate

* *Report on the Geology of Devon and Cornwall*, 1839, p. 94.

Falmouth
District.
(Mr. J. B.
Hill.)

and greyish green slate, rounded and sub-angular, together with angular pieces of white quartz. This part of the rock is generally fine-grained. The coarse conglomerate begins with a fringe of similar material, which also forms the matrix of the coarse mass. The larger boulders are made up of slate, quartzite, and vein-quartz. Many of the quartzite-blocks are of huge size; the smaller boulders of this material are generally well-rounded, as are also many of the fragments of white quartz. In addition to these fragments, which have been derived from rocks in the immediate neighbourhood, boulders of foreign material are also present, consisting of granitic and felsitic rocks, some of which are foliated: quartz-felsite and green schistose fragments, some of which are probably referable to the hornblende schists of the Porthalla district to the southward, while granitic and felsitic fragments may have been derived from the older rocks of the Lizard; at least they do not resemble the granite and associated rocks that lie to the north of this part of Cornwall. These far-derived materials are generally in a highly decomposed condition; they have also suffered brecciation from the stresses to which the Conglomerate has been subjected in common with the rest of the rocks of the district. Amongst the fragments of green rocks in the Conglomerate, one which was very serpentinous but highly fissile, unfortunately could not be extracted from the rock. Whether it should be associated with the Lizard serpentines, must remain doubtful. BOASE, indeed, has stated that fragments of serpentine and diallage-rock occur. DE LA BECHE observed hornblende slate, but could not detect serpentine or diallage-rock. Since the time of DE LA BECHE'S survey the existence even of pieces of the hornblende-slate has been doubted, no subsequent observer having detected it. MR. HILL'S observations tend to confirm DE LA BECHE'S statement. If the fragments of foliated granite have, as is probable, been derived from the Lizard district, serpentine may perhaps yet be found included in it. It must be borne in mind, however, that the granite and other igneous fragments, supposed to have been derived from that district, are generally much decomposed, so that the chances of so soft a rock as serpentine surviving attrition during transport might not be great. Although better able to resist severe movements of the terrestrial crust than the slaty rocks among which it lies, the Conglomerate has undoubtedly experienced similar stresses. Its upper layers have yielded to the movements as completely as the slates on either side of it. Moreover it is traversed by planes along which shearing has taken place, so that its constituent boulders have sometimes been broken across. Thin quartz-veins occasionally traverse both boulders and matrix. The quartzite boulders are sometimes almost welded into the gritty parts of the Conglomerate. A mica-trap dyke rises in the Conglomerate, in which it is no doubt intrusive, although its junctions with that rock are not seen. No fragments of it occur in the Conglomerate. The mica-trap is of the normal type of the dykes which in this district cut the Portscatho slates.

The quartzite is first seen on the south side of Nare Point, but on account of the coarse brecciated structure that has been previously described as occurring in this neighbourhood, it cannot be continuously followed. It occurs here as a lenticle about 10 feet long and 5 or 6 feet wide. A little further south, between Nare Point and Nare Head, the quartzite seen a little inland above the cliff probably represents the parent mass from which this large lenticle has been isolated. It is a grey compact rock which has suffered a great deal from the brecciation of the district. Its interstices are filled with vein-quartz, consequently it is a mixture of quartzite and secondary-quartz. Except that it is more brecciated, it is similar in character to the quartzite of Carne in Gerrans Bay. The thin limestone seen near Porthalla also resembles the limestone at Gidley Well in Gerrans Bay.

Besides the quartzite of Carne and the limestone of Gidley Well, the Veryan series of the Gerrans Bay district also contains a conglomerate, and is thus brought still further into relation with the strata between Dennis Head and Nare Point south of the Helford River. Indeed, the evidence furnished by a study of the two sections is ample for the correlation of the rocks in the two areas. DE LA BECHE clearly recognised the probability of their identity,* although the Veryan beds were coloured on his map as Lower Silurian, while what must be regarded as their equivalents south of the Helford River were coloured as Devonian. As the Veryan beds have been determined by paleontological evidence to be Lower Silurian, it is clear that strata of Lower Silurian age extend still further to the south-west, and that they form the northern boundary of the Lizard mass of eruptive rocks.

The positions of the four groups of strata enumerated in the table on p. 88 were given last year mainly as they appear on or near the coast line. But as these strata have since been traced well into the interior of the county, a better idea of their geological range can now be afforded.

The Veryan group, as we have already seen, after being lost in Gerrans Bay, reappears on the Meneage Peninsula to the south-west. It is then succeeded further west by the Portscatho group, which is well exposed along the coast line from Gerrans Bay to the Zoze Point. On the west side of the Carrick Roads, the Portscatho slates occupy the country between Falmouth Bay and the Helford River, from which they continue in a south-westerly course. From Pendennis Point they have an average north and south strike as far as Truro, and occupy the broad tract of country between that place and Gerrans Bay. The Mylor series (No. 4) covers an area of perhaps equal extent west of a north and south line between Truro and Falmouth. The Variegated Slates (No. 3), which lie between the Portscatho slates and the Mylor series, have been ascertained by the recent mapping, as far as this district is concerned, to be of much smaller extent than the two divisions

* *Op. cit.*, p. 25

Gerrans Bay. which it divides. Some further particulars may be given in addition to what was stated last year in reference to the several groups.
(Mr. Hill.)

In respect to the Portscatho slates, indeed, little has now to be added to the former description. They are almost continuously exposed along the whole line of coast from Gerrans Bay to the head of Helford River, and the greater part of the estuaries that strike inland from the Carrick Roads traverse this series of strata, so that, as it can be followed in continuous coast-sections across the strike from the mouth of Falmouth Harbour to Truro and Tresilian, unusual facilities are afforded for its detailed examination.

The Variegated Slates which form a well-marked belt at Falmouth cannot be so continuously traced. Between Falmouth and Truro they appear in lenticular strips, either as infolds within the Portscatho series or else as partitions between the Portscatho and Mylor series, while occasionally they may be seen as infolds within the area of the Mylor series. The axes of the isoclinal folds into which all the groups of strata have been thrown, do not correspond with the general strike of the stratigraphical zones but cross it rather obliquely, so that the mapping brings out several more or less parallel lenticular masses of the Variegated Series along a zone oblique to their longer axes, the several repetitions being due to isoclinal folds. These infolds are never found very far from the general boundary of the two adjoining series, except near Ruan Lanhorne, where two such patches occur within the Portscatho series, but indicating probably the upward limit of the Portscatho series at that place. The ground southwards from Falmouth affords similar evidence. The large belts at Falmouth and Maen Porth, apparently, "nose out," and the section along the Helford River which crosses the strike shows numerous zones of this series interfolded with the Portscatho slates. So close are these intercalations that in many cases it is quite impossible to separate the stratigraphical divisions on the map.

It was pointed out in last *Summary* that the Variegated Slates of Falmouth are more arenaceous than the series at St. Mawes, and as these are carried still farther to the south-west, they are found to be mainly arenaceous, almost to the total exclusion of argillaceous material, so that at Helford River they are represented almost entirely by buff sandy beds. Hence the alternations in colour from the green argillaceous to the buff sandy type are also lost, and consequently, instead of being variegated they are here of a uniform buff tint. Within this series of strata, both at Falmouth and at St. Mawes, narrow zones of sharply-contrasted purple and green slates have been observed, likewise to the north of St. Mawes, between Mesack Point and Turnaware Point, where rocks of this character are strongly developed in the Variegated series.

The Mylor series of finely-striped slates has been found to present a remarkable brecciated structure, to which brief allusion was made last year. So uniform was this character of the series

over large areas, that this particular structure was supposed to (Gerrans Bay. be due to original conditions of deposit, rather than to secondary (Mr. Hill.) processes of deformation. The field-work of last season, however, has revealed that the brecciation is not so common as was believed from the mapping of the strata between Falmouth and Restrongulf Point. The structure in question seems to be more or less confined to the latter locality, the outcrops further west and north being practically free from it. It is probably the result of the stresses to which the beds have been subjected. Its extent may be gathered from the fact that in some places it may be continuously followed across the strike for over half a mile, the strata being made up of a mass of fragments from the size of peas up to 5 or 6 inches in length, enveloped in a slaty matrix and with their flat sides lying in more or less parallel planes. These breccias clearly consist of the same material as the non-brecciated part of the same group, which is composed of inter-laminations of pale and dark argillaceous, occasionally pale siliceous material. The fragments are, as a rule, angular, but some are well rounded. Although direct evidence of their origin is not often forthcoming, yet, occasionally, stages may be detected in the process of manufacture which if carried a step further would have resulted in the production of isolated fragments. Besides having been thrown into numerous isoclinal folds, these strata throughout their whole material have been affected. The Mylor series, from the varying nature of its inter-laminations and the corresponding variations in their ability to resist crushing, appears to have been unable to overcome the main strains without this process of brecciation. Still, for the most part, this structure is evidently rare: it occurs only in the neighbourhood of faults, and is evidently the last stage after the folding. The separation of the fragments has been due to the limbs of folds being isolated by the movements, which have produced a structure somewhat similar to the coarser lenticular structure in the section between Falmouth Bay and the Nare Point. There has been a combination of minute over-folds and thrusts. Instances may occasionally be seen where the disruption of the folds is not quite complete, and where the almost isolated folded limb precisely resembles the separated fragments. The phenomenon appears to be related to that described by MR. LAMPLUGH in his paper "On the Crush Conglomerates of the Isle of Man." In the Cornish examples, however, there can be no doubt that the alternating materials of which the strata are made up has been a potent factor in this type of deformation.

The brecciated structure now described as so prominent a feature in the Mylor series is not confined thereto. A similar structure on a large scale may be seen south of Helford River, even in the Mylor series itself at a distance from the brecciated areas. Feebly brecciated zones are met with in the neighbourhood of faults. Minor zones of brecciated material can likewise be seen in the Portscatho series, generally in thin bands near a fault where small angular fragments of slate may be found enclosed in a matrix of similar material.

Gerrans Bay.
(Mr. Hill.)

In Gerrans Bay in one of these bands of brecciated dark slate a crinoid stem was seen to be apparently unbroken. It would be almost impossible to separate this band from similar strata where the brecciated origin is clear. The rock seems to have been able to undergo considerable deformation as a whole while small portions were unaffected. The isolation of the fragments has sometimes been produced without folding: instead of faulting succeeding the folding, the stresses have resulted in the direct formation of movement-planes, which have isolated the fragments from the main mass.

The igneous rocks of the Falmouth districts, besides the granite and the quartz-porphry dykes, are of the types consisting of greenstones and mica-traps. The former, many of which are schistose, are confined to the Mylor series, while the latter are found in the other stratigraphical divisions. These are especially numerous along the Fal actions of the Portscatho series.

The margin of the granite being everywhere obscured, the ground has proved highly unsatisfactory for the study of the effects of contact-metamorphism on the slates. Although the boundary of the eruptive rock has been followed for nine miles, the actual junction of the granite and slates has only been observed at one place. Besides the knotted structure, referred to last year, muscovite and biotite have also been developed in the slates. The mica increases in abundance towards the granite and has been observed as far as half-a-mile away from the line of contact. It occurs in minute scales but in considerable quantity, and both micas in about equal amount, but white mica is more confined to the immediate neighbourhood of the granite, whereas black mica occurs equally over the whole aureole where a micaceous constituent is present. The knotted slates have sometimes been observed at a distance of a mile and a-half from the nearest visible granite.

As pointed out in previous Reports, the structures of the stratified formations in the south of Cornwall are identical with the structures of crystalline schists. In the Falmouth district, so far as yet examined, true slates have not been met with. The strata have been thrown into a series of isoclinal folds accompanied by small faults. With these folds and faults minor structures have been set up until the whole rock has often become a mass of minute folds and thrusts with their accompanying strain-slip cleavages. These processes, as we have seen, have been carried so far that "crush-conglomerates" have been produced on a large scale. It is evident from a study of this district that had the rocks been subjected to these stresses at a greater depth and below the zone of fracture where they would not have been so free to move, they would have been converted into true schists. They possess now every structure of schists, but the mineralization has been wanting.

The visible dip of the rocks is of no value, except as registering the inclination of the limbs of folds. As an illustration of this fact, it may be pointed out that although the strata have a steady

dip to the south-east between Falmouth and Truro, and we are apparently crossing the strike from the coast to the heart of the county, yet instead of getting deeper in the stratigraphical series we are on precisely the same geological horizon at Truro as at Falmouth, the intervening ground being made up of a succession of isoclinal folds.

Age of the Stratified Rocks in the Falmouth District.—The limestones and quartzites of the Vervan Series contain fossils which determine these beds to be Lower Silurian, and they were recognised as such by DE LA BECHE, and coloured accordingly in his map. The Conglomerate already alluded to as occurring at Nare Head in Gerrans Bay, and at a headland bearing the same name south of the Helford River, contains boulders and pebbles of quartzite and not improbably marks a break between the Upper and Lower Silurian formations. Although the succession from the Vervan series to the Mylor series is apparently a descending succession, the true position is probably the reverse, and the Portseatho, Falmouth, and Mylor series may be Upper Silurian. At present no palæontological evidence is available to settle the stratigraphical position of these strata, which in the meantime can only be provisionally determined by their relations to the Lower Silurian rocks. If this interpretation should prove to be correct, the Devonian system is not represented in this part of Cornwall.

OLD RED SANDSTONE.

Ross-shire and Inverness-shire.

A few additional particulars have been collected during the past year regarding the lower division of the Old Red Sandstone of the basin of the Moray Firth. It has long been known that detached outliers of the formation are scattered over the schist-country of Sutherland and Ross. A number of previously unobserved outliers of this nature have been met with in the progress of the Geological Survey through these counties. Two of them which were detected by MR. GUNN to the north-east of Loch Luichart in the east of Ross-shire* have now been mapped by MR. PEACH. They consist of breccia which caps the two mountains Beinn a Bhric and Beinn nan Cabag. In placing the details of their structure on the maps MR. PEACH has noticed further evidence of the exceedingly uneven surface of schists on which these breccias and conglomerates were deposited. In particular the remarkable augen-gneiss which forms so conspicuous a feature in the geological structure of that district rose as a ridge above the rest of the crystalline rocks in the waters of the Old Red Sandstone basin.

Loch
Luichart.
(Mr. B. N
Peach.)

Further progress was made by MR. HORNE in mapping the Old Red Sandstone in the Valley of the Nairn to the East of

Strath Nairn
Inverness-
shire. (Mr.
Horne.)

* Annual Report of Geological Survey for 1896, p. 53.

Inverness. In tracing its boundary along the west side of the valley he observed that the basement conglomerate contains pieces of the surrounding granulites and biotite-gneisses, and also blocks of porphyrite and felsite.

Beaully
District. (Mr.
Hinxman.)

In the same basin a further tract of Old Red Sandstone has been mapped by MR. HINXMAN from his station at Beaully. He has traced the western limits of the formation northwards to the Conon at Torrachilty. Above Clachuile Inn the river flows for some distance over a series of gently-inclined grey micaceous shales and flagstones, the general direction of dip being east-south-east. At Newton, a short distance below the rapids, the beds roll over towards the west, and rest at much higher angles. Immediately below the fall the shales are intercalated with and pass up into a well-bedded conglomerate, composed of rounded stones of moderate size, and altogether different from the coarse tumultuous breccia of Glen Orrin and the Beaully river.

The junction between the conglomerate and the Moine schists at the fall is a faulted one, and is accompanied by a considerable amount of disturbance and brecciation in the schists. The line of this fault can be followed through the woods of Coille Mhor to Glen Orrin, where it leaves the conglomerate, and passing into the muscovite-biotite-gneiss has determined the northerly course of the Orrin above Strathan for a short distance.

The outcrop of the grey shales is marked by a line of sulphurous wells of varying strength. Some of these springs rise in the bed of the river, and are only seen when the stream is at a low level. Others appear at Muirton Mains, Coul of Fairburn, and in the river Orrin at Balno. There is also a well-known spring of this nature just outside the village of Beaully, indicating the presence of the shales at this point beneath the thick covering of recent marine alluvium.

Lorne, Argyllshire.

In the *Summary of Progress* for 1897, and in that for 1898 accounts have been given of the interesting discovery of remains of fishes and other organisms in the sedimentary strata associated with the volcanic series of Lorne. The occurrence of *Cephalaspis* definitely proved these strata to belong to the Lower Old Red Sandstone. During the past year further information has been obtained regarding the fauna that was contemporaneous with the *Cephalaspis* in the ancient water-basin of Lorne. Remains of Ostracod crustaceans have been detected, and though their state of preservation is not as perfect as could be wished, their forms are at least generically recognizable. Possibly some layer of stone may yet be met with in which not only these, but other organisms have been more perfectly preserved. Paleontological notes on this subject will be found on p. 186.

In the Lorne basin of the Lower Old Red Sandstone further field-work by Mr. R. G. SYMES has added to our knowledge of the extension of the sedimentary portion of the formation in that region, and at the same time has brought to light fresh points of interest in connection with the remarkable volcanic phenomena of this basin. Thus he has detected several previously unrecorded outliers of the conglomerate in the neighbourhood of Kilmelfort. One of these, of considerable size, lies a mile and a-half east of Kilmelfort Hotel, and to the east of Loch a' Mhinn. The material of which it consists is entirely different from that of any other conglomerate in the Oban district. It is made up at its base of large blocks, chiefly of porphyrite, epidiorite, limestone, schists, slates, and some quartzites, with but little matrix. At first it was supposed to be an agglomerate from the angularity of its constituents, but when the ground was more fully examined the upper portion of the mass was found to be similar to other parts of the Old Red conglomerate. North-east of Loch nan Ban, where the conglomerate rests on a floor of felsite which in places is highly porphyritic, the greater proportion of its blocks consists of that rock. On the west side of the exposure the lower part of the mass lies on thick limestones, phyllites, and epidiorites. Occasional pebbles of vein-quartz are met with in the higher layers, but bedding is not apparent, nor any trace of intercalated sandstones or shales. The greater number of the blocks in this rock near Loch a' Mhinn consists of a pink feldspathic porphyrite. The conglomerate is there cut by a pink feldspathic porphyritic dyke similar to those found elsewhere, rising through the Lower Old Red Sandstones and their associated andesites. These dykes trend from north-north-east to south-south-west. The strata exposed in this outlier must in some places be as much as 400 feet. The conglomerate here has no andesite capping, nor have andesite blocks been noted among its constituents.

Oban and
Kilmelfort
District. (Mr.
R. G. Symes.)

North-east from Loch Losgain Beg another outlier of conglomerate extends from Loch a' Mhinn westward, and is found adhering to the quartzites and epidiorites on the east side of Barr Kilmhealaird. It is composed almost entirely of decomposed felsite-blocks, set in a matrix of comminuted material of the same kind. On the southern shore of Loch a' Mhinn a third small outlier has the same composition as that last mentioned, both of them being totally different in their ingredients from the mass east of Loch a' Mhinn, which is only distant a couple of hundred yards. From the considerable area covered by the conglomerate to the south and east of Loch Fear, near Kilmelfort, the rock might be supposed to be well developed there, but as it lies horizontally, and has had its protecting cover of andesitic lavas removed by denudation, its thickness in some places does not exceed a few feet.

At the foot of the waterfall from Loch Fear the basement-beds of the Lower Old Red Sandstone consist of thin purple shales lying below the conglomerate and resting on siliceous schists and limestones. Such an intercalation is most unusual throughout

Oban and
Kilmelfort
District.
(Mr. R. G.
Symes.)

the Oban district. It may be remarked in passing that under the shallow waters of Loch Fear a beautiful ice-polished surface of the conglomerate may be seen wherein, as in a kind of mosaic pavement, the pebbles of quartzite, pink porphyrites, vein-quartz, and epidiorite are displayed. The irregular floor on which the conglomerate was laid down is well seen to the west and north of Loch Losgain Beg, a mile east of Kilmelfort, while on the western slopes of Barr Kilmhealaird, the way in which the conglomerate passes down into cracks in the schists and epidiorites is conspicuous. These prolongations of the conglomeratic material downward might here and there be mistaken for actual intercalations of the conglomerate in the schistose series underneath. This series here consists of schists (phyllites) with calcareous bands, quartzite, epidiorite, porphyrite, and felsite with flow-structure. All these rocks are represented among the pebbles in the conglomerate, which are mostly sub-angular, and never quite well rounded. Here, as usual, they are local in origin. Near the outcrop of the porphyrite, blocks of that rock more than two feet long are found in the conglomerate. No fragments of andesite like that of the true lavas have been observed in this exposure.

The general local derivation of the materials in the conglomerates is well shown all over the Kilmelfort district. Thus on the hill side above Loch nam Ban, two miles east of the village, the rock is so much made up of the pink felsite upon which it rests that, but for some rounded pebbles of quartz that stand out on weathered surfaces, it might easily be mistaken for an igneous mass. The same close relation to the underlying material may be observed further to the east, in the stream which joins the Duchara Burn, near Lagalochan. At both places the compact conglomerate is the highest bed exposed in the section east of Loch a' Mhinn. About a quarter of a mile above the road, crossing the stream already alluded to, the conglomerate has been derived from the white decomposing felsite on which it rests, while nearer the road it is fine-grained and hard, resembling the conglomerate seen above Loch nam Ban. Along this stream a large north-north-east and south-south-west fault runs, with a downthrow to the east, whereby the compact conglomerate on the top of the series is thrown down against the epidiorites on the west side of the stream.

A further illustration of the uneven and cleft surface on which the Old Red conglomerates of this district were deposited may be observed on the shore, about a mile and three-quarters to the south-west of Kilmelfort close to the old Fort, and a little west of a porphyrite sill there exposed. The schists are here traversed along their planes of schistosity by a series of cracks now filled with a brecciated conglomerate similar to that which occurs on the hill side to the north of Loch Losgain Beg above mentioned. Although the overlying conglomerate has disappeared there can hardly be any doubt that these veins of its material belong to it, and represent the local base of the Old Red Sandstone, of which so large a part has been removed from this area by denudation.

North of Loch Tralaig, about three miles north of Kilmelfort, and to the east and west of Innies farm-house, thin beds of conglomerate appear from under the andesite. Again, to the north-west of Corriellorne, beds of conglomerate form the floor on which the andesites rest, while east of Tralaig, and north-east from the farm-house of Druimnashallag some red and purple shales intervene between the lavas and the epidiorites. These are the only exposures of the sedimentary representatives of the Lower Old Red Sandstone to be met with in that part of the district for a distance of six miles from east to west. In the Pass of Melfort, at the sharp angle in the road, some red, horizontally-stratified deposits, with black layers, about four feet thick, may possibly fill an enormous sand-crack. MR. TEALL found them, on examination of specimens, to be composed of disintegrated andesite.

Oban and
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To the north of Loch Avich, seven miles east of Kilmelfort, and west of Drissaig, the conglomerate dips to the east, underneath the lavas, and attains some thickness. It here differs from the conglomerates previously enumerated inasmuch as its chief constituents are fragments of andesite and epidiorite. The surface of the blocks in this mass has been well polished by ice, the direction of striation being east and west. This outcrop of fragmentary material may belong to a somewhat later part of the series than those conglomerates which have derived their constituents entirely from the schist-platform below; at least, it was not deposited until the eruption of the andesites had begun, whereas in the other examples referred to, no fragments of these lavas have been as yet detected.

A large part of the southern outcrop of the andesitic lavas of the Lorne region has been mapped during the past year. The margin of this volcanic area presents an irregular east and west line of escarpments rising above talus-slopes. The only gap or road through this area in a north and south direction is that of the pass of Melfort, formed by the River Oude, which has cut its way through the thick mass of lavas. At the southern limit of the andesites exposed in the road in the Pass of Melfort, close to the avenue gate to Melfort House, the volcanic sheets are seen to rest upon phyllites and epidiorites, with no intervening layer of sedimentary deposits. No outliers of the andesites have been noted to the south of Kilmelfort, or beyond the southern edge of the volcanic area.

When the mapping of the andesite-flows was in progress in the neighbourhood of Loch Tralaig, it was difficult to decide whether a large east and west fault runs along the southern shore of the lake, throwing down the volcanic rocks on the south against phyllites and epidiorites on the north, or whether denudation had removed all the lavas on the west side of the loch, so as to expose the schists, quartzites, epidiorites, and intrusive dykes. The section of the lavas to be seen south from the lake shows them to be almost horizontal. No trace could be found here of tuffs like those north and south of Loch Etive, nor are there any acid lavas such as have been found near Taynuilt and Airds Bay, in the north-east portion of the Oban district.

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The greatest thickness of the entire series of andesitic lava-sheets between Tralaig and Kilmelfort is possibly not more than 500 feet. It has now been ascertained that the greatest development of these lavas occurs between Lochs Etive and Creran, and that the thickness of the sheets gradually lessens towards the south. About half a mile south-east of the shepherd's house of Maolachy, four miles east of Kilmelfort, an irregular mass of intrusive acid igneous rock in all probability belongs to a neck or volcanic vent. It is elongated in an east and west direction, and is about a quarter of a mile long and about half as broad. MR. PEACH, who twice visited the ground, has furnished the following notes on the field relations of this mass:—"It consists of an acid igneous rock, probably a very acid andesite, or perhaps a rhyolite, in which evidence of flow while the rock was in a very viscid state is everywhere conspicuous, the whole rock being now quite platy and its layers so highly crumpled as to simulate a puckered schist. The planes which separate these plates conform in a remarkable manner with the outward edges of the mass, and are either more or less vertical or dip inwards at high angles. Often near the edge the mass includes numerous blocks of the surrounding dark slates or epidiorite sills. It also contains broken-off portions of material similar to itself, which show flow-structure in a marked degree. So numerous are these fragments in some places that the rock looks like a brecciated conglomerate or agglomerate. The nature and the source of this breccia are well exhibited in the stream which skirts its north-western limit, where its contact with the sedimentary rocks is best exposed. Here the line of contact with the dark schists and limestones can be followed for about 200 yards. The rocks are much shattered, and their junction with the igneous mass is somewhat irregular, but the latter rock is seen to have flowed upward, conforming to the uneven surface, and catching up innumerable fragments of the black slates and limestones, as well as bits of its own chilled outer layers, and involving them in the still flowing viscous rock. This is in all probability a neck or vent which may have supplied the material of the more acid lavas and tuffs of the volcanic platform of Lower Old Red Sandstone age in Lorne."

Near Loch nan Losgain Beg several other masses of a similar flow-breccia are to be seen. Some parts of these contain more broken up fragments than matrix. But that they are truly of eruptive origin can be shown in many cases where they act as dykes or sills, and cut both the rocks of sedimentary origin and the epidiorite sills. They are in turn cut by the tertiary basalt-dykes. They are all probably of the age of the Lower Old Red Sandstone, and belong to the later phase of vulcanicity in the history of the lavas of Lorne. They are usually associated with "porphyrite" dykes, and may be regarded as not improbably continuations of such dykes as have continued to flow after having cooled to a very viscid condition and partially solidified. Flow-structure is also exhibited at the edge of some of the porphyrite sills.

County Waterford.

While the revision of the Silurian areas has been in progress it has occasionally been necessary to carry the investigation into the surrounding tracts of other rocks. This prolongation has been especially imperative in the south of the County of Waterford on account of the complexity of the coast-sections and the accumulating evidence that much of the igneous material there developed, though enclosed within the area of the Silurian rocks, belongs to a later than the Silurian period.

Bunmahon
District.
(Mr. J. R.
Kilroe.)

The age of the red sandstone, grits, and conglomerates, exposed on the coast at Bunmahon, has long been in dispute. The strong resemblance of these strata to the Old Red Sandstone of the neighbouring Comeragh region induced the original surveyors to consider them of corresponding age, and they were so represented upon the first edition of the one-inch sheet (No. 178), published in 1857. Their apparent interstratification with supposed volcanic tuffs and lavas of Silurian age, subsequently led to the abandonment of this view, and to the relegation of these red rocks to the Lower Silurian group, under which colour they appear on the edition of the map issued in 1863, which has not since been changed. A more recent examination of the district led the present Director-General of the Survey to question the correctness of the alteration and to express the opinion that the original view would not improbably prove to be correct. Believing that the igneous rocks to the east had been truly assigned to a Lower Silurian date, he thought it probable that a second set of igneous rocks existed which could not be older than the Old Red Sandstone.* Still more recently MR. COWPER REED has concurred in the original view. He mentions the superposition of the red rocks upon denuded igneous masses which were supposed by the authors of the revised edition of the map to be interbedded and contemporaneous. He bases his opinion as to the age and position of the conglomerates upon their relation to the igneous rocks, conjointly with their having undergone great disturbance and dislocation after Old Red Sandstone times. As the basal conglomerates at Ballydowane Bay—the principal place in which the red rocks are to be seen—contain pebbles of igneous material identical in character with that which forms the greater part of the perplexing intrusion-breccia at Bunmahon Head, it is not difficult to account for these differences of opinion. Accordingly MR. KILROE has devoted some time to a careful examination of the perplexing evidence, and he has supplied some notes of the results which he has so far obtained.

Occurring in five small isolated tracts, and usually showing high dips or set on end, the red rocks seem to lie in deep synclinal basins, the longer axes of which correspond with the trend of the neighbouring igneous bands, with the general

* *Ancient Volcanoes of Britain*, vol. i., p. 251

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direction of cleavage, and with the strike of the highly inclined Old Red Sandstone near Dungarvan. Though much faulted the strata present a clear succession at several points along the coast.

An important section on the cliff in the middle of Ballydowane Bay shows the following succession in ascending order, viz. :—

(a.) Basal deposit, several feet thick, consisting wholly of igneous detritus—green and grey felsites and some basic (?) rocks; pebbles for the most part well-rounded. The beds rest at about 80° against igneous rocks similar in character to most of the pebbles, and weathering, specially near the junction, into a conglomerate-like mass, so that the line of demarcation between the two rocks is not distinctly traceable. No true tuffs or other truly volcanic rocks have been recognised either in the material of or near the basal deposit.

(b.) Red argillaceous grit, with massive bed of grey grit.

(c.) Conglomerate, consisting chiefly of white quartz-pebbles embedded in a red sandy matrix.

On the shore at the west end of the bay the adjoining igneous rocks are to be seen invading green grits and epidotic and serpentinous fossil-bearing Silurian limestone. On the east side of the bay the argillaceous grit, which as usual passes up into quartz-conglomerate, rests directly upon igneous rock, which, at this point, also penetrates green calcareous grit. The boundary here seems to be a thrust-plane, and though the hade (38°) corresponds closely with the dip of the immediately over-lying strata (38° to 45°), the dislocation may have cut out the conglomerate which elsewhere occurs at the base of the series, and appears at the other side of the same synclinal basin. A vertical fault, almost parallel to the break just mentioned, cuts out the basal deposit at one point, but leaves a small thickness of it resting against igneous rocks, where it is seen to consist, as at other points, of fairly well-rounded igneous materials.

Close to Bunmahon Head the red grits are faulted against green felsites, and pass up into quartz-conglomerate. At the ore-yard and site of engine-house, Knockmahon, quartz-conglomerate overlies red grits, which commence with a fine breccia of igneous detritus, resting upon and against green felsite, which in the immediate vicinity penetrates Silurian fossil-bearing calcareous grit.

The section of undoubted Old Red Sandstone, near Ballyvoyle Head, presents a series of strata closely resembling those now described. Red argillaceous grit is there seen to intervene between quartz-conglomerate and the base of the series; while local blocks scattered on the beach, and probably detached from the basal beds at present concealed, show that these beds consist of conglomerate formed of igneous materials similar to those at the base of the Bunmahon series. This fact is all the more significant since the Old Red Sandstone floor in the Ballyvoyle coast section is formed of dark-grey and black slate, penetrated by a few felsite dykes. The Bunmahon conglomerates may therefore, with little hesitation, be regarded as belonging to the same series as the

strata near Dungarvan, which are known to be of Upper Old Red Sandstone age. The igneous rocks which preceded the red rocks at the one place also preceded those at the other; and as these igneous rocks have invaded Lower Silurian strata, while fragments of them abound in the overlying conglomerates, their intrusion must date between the Lower Silurian and Upper Old Red Sandstone epochs. Bunmahon District.
(Mr. Kilroe.)

But not only do the red strata contain abundant detritus of eruptive rocks, they have themselves been invaded by some of these rocks. At the southern end of the little promontory at Bunmahon Head they are penetrated by an intrusion which is seen to cross obliquely some twenty feet of quartz-conglomerate and red grit, within a distance of about 100 yards. Both igneous and sedimentary rocks at the junction are crushed, but not to such an extent as to obliterate the evidence of intrusion. The red strata, moreover, near the junction contain injections of a green igneous rock; and the adjoining igneous mass, includes fragments which resemble, if they are not, those of red grit. Like some of the rocks further east, to which reference has already been made, this mass is composed of green felsites, and perhaps andesites, in rounded lumps, which are embedded in and cut up by, a more basic material. The rock is now a coarse aggregate, which might readily be taken for a volcanic agglomerate.

A close resemblance is noticeable between this basic rock at Bunmahon Head and another which contains numerous quartz-pebbles near Mount-Kennedy, eight miles to the north-west. This highly vesicular rock afforded material to the Old Red strata overlying it. Pebbles of similar material were observed in local blocks taken from the base of the Old Red Sandstone at Ballyvoyle Bridge.

CARBONIFEROUS.

The field-work of the Survey among Carboniferous rocks during the past year has lain in the coal-fields of North Staffordshire and South Wales. In each of these regions satisfactory progress has been made in mapping not only the coal-fields, but also the surrounding areas, which, though largely covered by younger formations, must be surveyed in order to allow of the publication of the various one-inch sheets in which the coal-bearing tracts are represented.

North Staffordshire

The revision of the North Staffordshire coal-field and surrounding country has been continued under the supervision of MR. FOX STRANGWAYS by MESSRS. BARROW, GIBSON, POCOCK, and WEDD. MR. FOX STRANGWAYS has himself been mainly engaged upon the Jurassic tracts that lie to the east of the Rushton Spencer.
(Mr. Fox Strangways)

Rushton
Spencer.
(Mr. Fox
Strangways.)

Leicester coal-field, his share in the North Staffordshire having been mainly that of taking general charge of the mapping by his colleagues. He reports that at Rushton Spencer, five miles to the north-west of Leek, a group of sandstones and shales which is there developed, has been considered to represent the Permian rocks of that district,* but that the strata precisely resemble the sandstone and shales which further south have been mapped as part of the Carboniferous system. He thinks that there can be little doubt that they belong to the "Yoredale series," an opinion which is shared by his colleagues, MR. BARROW and MR. GIBSON.

Leek District
and Cheadle
Coal-field.
(Mr. George
Barrow.)

Resuming work near Leek in the spring, MR. BARROW completed the mapping of the inlier of Bunter strata through which the Churnet flows. In addition, so much of the Carboniferous shales and grits was examined as sufficed to finish the area allotted to him. The examination of the Cheadle coal-field was then commenced, and the same plan was followed as in the previous season. The grit-bands immediately below the Coal-measures were first traced, as it has been found that they indicate clearly the presence and direction of faults, which are so much more difficult to trace in the softer coal-bearing strata. Starting from this basal group, the examination of the overlying groups was proceeded with, and a higher and inner zone was completed, including the Woodhead coal. The tracing of the coal-seams above this horizon has proved difficult and tedious owing to the soft nature of the strata, and the almost featureless character of the country. Indeed some portions of the work could not be done without the assistance of mining information as to the ascertained structure of the ground, and this information has been willingly afforded by those connected with the collieries. The base-line of the Bunter formation which forms the southern limit of the visible coal-field has also been traced, and only a few patches of obscure ground now remain to complete the survey of this area.

Beginning with the oldest or Carboniferous series of strata, MR. BARROW reports that these fall naturally into five groups, which have probably only a comparatively local value. They are as follows in descending order :—

1. The White-weathering group with numerous coal seams. Thickness, 1,200 feet.
2. The Woodhead coal with accompanying dark shales and the Kingsley sandstone below. Thickness, 230 feet.
3. The Dark Shale and Gannister group. Thickness, 300 feet.
4. The first and third Grits with the intervening dark shales ; thickness, 300 feet. (Millstone grit in part.)
5. Dark shales with marls and thin sandstones, the latter passing to coarse grits in a south-easterly direction ; thickness not yet known. (Yoredale beds on the maps.)

* See Green, "Geology of Stockport." *Mem. Geol. Survey*, 1866, p. 36.

1. *The White-weathering Group*.—As no complete account of this group has yet been published, the following section of this part of the Coal-measures in descending order may be given here:—

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	Ft.	In.
Two yard Coal - - - - -	5	6
Measures - - - - -	54	0
Getley Coal - - - - -	2	0
Measures - - - - -	20	0
Half yard Coal - - - - -	2	6
Measures - - - - -	61	0
Yard Coal - - - - -	3	9
Measures - - - - -	60	0
Litley Coal - - - - -	2	9
Measures - - - - -	35	0
Four-foot Coal - - - - -	4	0
Measures - - - - -	60	0
Coal - - - - -	1	6
Measures - - - - -	80	0
Dilhorne Coal - - - - -	6	0
Measures - - - - -	190	0
Alecs or Stinking Coal - - - - -	3	9
Measures - - - - -	55	0
Foxfield Coal - - - - -	1	8
Measures - - - - -	64	0
Coal - - - - -	1	5
Measures - - - - -	130	0
Cobble Coal - - - - -	1	3
Measures - - - - -	55	0
Coal - - - - -	1	1
Measures - - - - -	95	0
Rider Coal - - - - -	1	6
Measures to Woodhead Coal - - - - -	125	0

Though numerous seams of coal occur in this group, the Yard and the Dilhorne are the only thick seams of good quality. Of the thinner seams the Half-yard and the Cobble are always of fairly good quality, while the others either vary locally or are persistently of a poor character. The strata of this group are characterised in the field by their white weathering, their principal constituent being a pale marly shale or clay. When under pressure this is a fairly hard rock, but when once wetted it rapidly swells up and tends to close up the workings, thus adding greatly to the cost of winning the coal. All coals above the Dilhorne suffer more or less from this disadvantage.

Fresh or brackish-water lamellibranchs occur in thin grey bands throughout the group, while fish-remains, *Spirorbis* and *Carbonia*, are locally abundant. The strata, as a whole, may be claimed as essentially of fresh-water origin.

2. *The Woodhead Coal and Kingsley Rock or Sandstone*.—While the dark shales associated with the Woodhead Coal resemble the beds of the uppermost group in the fresh-water nature of their organic remains, they differ from them greatly in lithological character. In place of being soft, these shales are distinctly hard. In particular, the black shale immediately above the coal has a massive aspect when seen in stream-sections, and forms an excellent roof to the workings. As the floor is also a hard rock,

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this coal can be worked cheaply, and it is consequently the only seam at present worked to any extent in the Cheadle coal-field. About eight feet below the coal comes another black shale some thirty feet thick, which rests on the Kingsley rock, an alternation of thin sandstones and laminated hard sandy shales. This rock forms on the surface of the ground an excellent topographical feature, recognisable at a considerable distance. As it passes into the dark shales of the third group below, its limits can hardly be precisely fixed. But its distinctive characters are of great local value, for, as it can be easily recognised, it has supplied the key to the geological structure of the district.

3. *The Black-shale and Gannister Group* is characterised by its great amount of black shale which contains an essentially marine fauna, and thus differs from the higher shales, which otherwise closely resemble it. With the shales of this third group are associated numerous thin coal-seams. Of these all but one are either not persistent, or become so thin as to have often escaped notice. One, however, which is very persistent, is known as the Crabtree or Stinking (pyritous) Coal. It invariably possesses a hard shale roof containing abundant *Goniatites* and other marine fossils. There is reason to believe this coal, with its shale roof, to be continuous into Lancashire, and to regard this portion of the Coal-measures as the equivalent of the Gannister series of the country to the north. This view is strengthened by the fact that the sandstones of this zone often have a gannister-like aspect. Indeed the sandy beds below the Crabtree Coal often pass into a high-class gannister, which is now being worked in two places. At the base of this group lies the well-known Froghall Ironstone, which has been extensively worked in the Consall, Froghall, and Ipstones district. Detailed examination shows this seam to have been lenticular in form; practically the whole of the lenticle has been worked out. A feature worth noting in it is the fact that near Ipstones lenticles of coal occur in its upper part. The same phenomenon has been noted in connection with two ferruginous bands in the horizon below.

4. *Millstone Grit* (in part).—This group consists of the First and Third Grits, with the mass of dark shale between. In the area about Froghall and Ipstones these bands show much the same character and thickness as about Leek; the grits are probably slightly thinner, but the difference is not great. The shales between the grits are interesting, as they contain two hard shale-bands closely resembling the shale above the Crabtree Coal. The first lies about half way between the two grits, and is underlain by a mixture of coal and ironstone, the exact thickness of which has not been ascertained. The second shale-band lies about 10 feet above the Third Grit, and is underlain by the well-known Roaches Coal, which appears to extend like the Crabtree seam over a very large area. Unlike the latter seam, however, it thickens and thins locally, and in some places becomes little more than a smut. To the west of Ipstones this Roaches Coal is 2 feet 10 inches thick, and of fairly good quality.

A level which was driven into it to drain the water may be at least 300 years old. At the time when this level was made its construction must have been a feat of engineering. The fact that mining operations long ago attained a high standard of excellence in this part of Staffordshire is borne out by the discovery of extensive workings in the Froghall ironstone in the course of the more recent mining operations. All record of these workings is lost, yet it is clear that at least several thousand tons of ironstone must have been extracted from them. As the coal above the Third Grit is traced southward an association of interlaminated coal and ironstone is met with, similar to that in the two instances just mentioned. It is remarkable that the same somewhat exceptional conditions should have been repeated three times in the same area on different horizons. Such an association of coal and ironstone has not been met with on these horizons in any other part of the region.

On the west side of the Cheadle coal-field a very different development of these strata is met with. Starting from the cross-roads south of Wetley and proceeding towards Dilhorne, we find that the first grit thins away with great rapidity and indeed is no longer recognisable. The third becomes much thinner, though still sufficiently coarse to be distinguishable from an ordinary Coal-measure sandstone. If this rate of thinning were continued, in a short distance there would be little or no grit left. The cover of Bunter sandstone which comes on further south makes it impossible to say whether or not such a diminution takes place.

5. *The Zone below the Third Grit.*—A small portion of the rocks below the Third Grit has been mapped on both the east and west sides of the Cheadle coal-field. To the east, across the Churnet Valley, where the grits above are still thick, we find below the Third Grit, first a mass of dark shales associated with bands of marl and thin sandstone. Below these lie a number of comparatively thin bands of coarse grit. As this area is much faulted, these grits gave considerable trouble in the mapping, for they seemed to be parts of the Third Grit repeated by faulting. Fortunately the thickest of them has been sunk through and found to be only 30 feet thick, so that it could not be that bed. The detailed survey of the area has proved these grits to occupy the horizons of the thin hard sandstones (crowstones) of the Leek and Endon district, and it is now seen that the great mass of shale and sandstone of that district is a somewhat local phenomenon, for to the south-east these rocks revert to their more normal condition of coarse grits. On the east side of the Cheadle coal-field, however, where the grits are thinning away, no such coarse rocks occur in this lower zone. Though hardly so fine as the typical "crowstones" the sandy rocks are still fine in grain.

The progress of MR. BARROW'S field-work has once more impressed upon him the great vertical range of individual fossils in the Carboniferous system, and he contrasts the *Goniatites*

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of that system with the *Ammonites* of the Yorkshire Lias. If the rate of biological variation remained fairly uniform we must suppose that the Carboniferous strata were laid down with comparative rapidity. In the case of the grits and shales this acceleration of sedimentation may not present any serious difficulty, but it is not so credible in the case of the great mass of Carboniferous Limestone.

North
Staffordshire
Coal-field.
(Mr. W.
Gibson.)

The continued prosecution of the resurvey of the Pottery coal-field has been carried on by MR. GIBSON, partly with the assistance of MR. WEDD, while the surrounding Triassic areas have been mapped by MESSRS. POCOCK and WEDD. The following narrative of the work has been drawn up by MR. GIBSON:—

Among the Carboniferous rocks, several observations of scientific interest and commercial value have been made. At Weston Sprink, on a horizon between the Moss and Yard Coal, some purple shales, marls, and thin limestones are exposed in a marl pit. The shales have been traced some distance northward and found to be overlain by a red sandstone similar in appearance and texture to the Keele sandstone at the top of the Coal-measures. MR. JOHN WARD, of Longton, has obtained an interesting set of marine forms from this place. The fossils include *Aviculopecten papyraceus*, *Discina nitida*, *Lingula mytiloides*, *Pleuromutilus* sp., also a mytiliform shell and a small estheroid shell. The occurrence of *Aviculopecten papyraceus*, etc., high up in the Coal-measures is new to science.

Mention was made in the last *Summary of Progress* (p. 127), of the discovery by MR. GIBSON of an ironstone in Fenton Park marl pit, of which DR. POLLARD made an analysis from a carefully selected set of examples. A similar ore was found during the past year underlying the Chalky Mine Ironstone at the Clanway Colliery, Tunstall.

By the courtesy of MR. W. B. CLIVE, an analysis of this ore by MR. W. JACKSON, A.R.C.S., is here given:—

Ferrous oxide	-	38·88	per cent.	=	30·24	per cent.	iron.
Manganous oxide	-	0·89	"	=	0·69	"	manganese.
Lime	-	6·09					
Magnesia	-	3·34					
Alumina	-	7·90					
Silica	-	12·10					
Phosphoric acid	-	0·53					
Carbon dioxide	-	27·52					
Water (lost at 100°)	-	0·85					
Combined water	-	2·78					
		100·88					

On calcined stone 41·33 per cent. iron.

The ore lies directly under and contiguous to the Chalky Ironstone bands. This position makes it a valuable ore, since although of comparatively low grade, it can be got with the valuable Chalky Ironstone at little extra cost. It is hoped, therefore, that the ore will ultimately be used in the local blast-furnaces.

In the difficult region of Talke and Audley, MR. WEDD has found that the lowest productive Coal-measures are brought to or near the surface in anticlines which trend in a north-north-east direction, from Woodlane on the south to Harecastle on the north. The Ten Feet Rock, a thick sandstone above the Ten Feet Coal, and sometimes in conjunction with the "rock" associated with the Seven Feet Banbury Coal, plays a large part in the formation of the anticlinal ridges. As the highly-inclined seams are traced on the western limb of the anticline they are found at a comparatively shallow depth to bend sharply upward, and to assume an almost horizontal position up to a large fault, which can be followed from Madeley Manor to Audley Station, and has been variously estimated to have a downthrow of more than 300 yards to the west. On the downthrow side of this dislocation the strata are gently inclined to the west. This inclination has been proved by mining operations to hold for the lower coals, and can also be seen at the surface in the upper measures.

North
Staffordshire
Coal-field.
(Mr. C. B.
Wedd.)

West of Leycett and Audley Station the Etruria marls and Newcastle-under-Lyme series, as described in last *Summary of Progress*, dip to the west at a gentle angle. The field-work during the past year thus enables us to define more clearly the area occupied by Upper Coal-measures to the west of the Staffordshire anticline. The area exposed may be taken at two square miles. Under this tract the Bassey Mine Ironstone lies at a depth of 1,000—1,300 feet.

A band of limestone containing *Entomostraca* has been found in the Keele series at Moddershall. This band most likely lies at a higher horizon than those described in the *Summary* for 1898. A cream-white limestone has also been found in the Keele series in the Keele Park railway cutting, 311 feet above a dark limestone containing *Entomostracan* remains; obscure forms of plants have also been found in the same cutting. During the progress of some excavations in Keele Park, a coal one foot six inches thick was found in the red series. Some good, but unnamed, specimens of plants from the Keele Sandstone of Hartshill, from the collection of the late DR. GARNER, are preserved in the Museum of Stoke-upon-Trent. These, at MR. GIBSON'S request, have been examined by MR. KIDSTON, F.R.S.E., who has kindly furnished the following list of them:—

Sigillaria tessellata, Brongn, decorticated and showing fructification zone.

Calamites undulata, Sternb, &c.

„ *Schutzei*, Stur.

„ *Cistii*, Brongn.?

„ *Suckowii*, Brongn.

These additional facts tend to show that the Keele Sandstone series, as already suggested, is intimately connected with the Coal-measures.

A thin band of grey limestone with *Entomostraca* has also been found near the base of the Etruria marls in the Grange Marl Pit. Eleven distinct bands containing *Entomostraca* are

North
Staffordshire
Coal-field.
(Mr. W.
Gibson.)

now proved to exist in the Upper Coal-measures of North Staffordshire. They are distributed as follows through the several sub-divisions of that assemblage of strata:—

KEELE SERIES:—Four bands at different horizons:—*Carbonia*, *Spirorbis*.

NEWCASTLE-UNDER-LYME SERIES:—Two bands near the base:—*Carbonia*, *Spirorbis*, *Anthracomya calcifera*.* Fish-remains.

ETRURIA MARL SERIES:—Two bands near the summit and base:—*Spirorbis*, *Carbonia*.

BLACK BAND SERIES:—Three bands near the base, and thin bands of black shale with *Entomostraca* at several horizons:—*Carbonia*, *Spirorbis*, *Anthracomya Phillipsi*, *Carbonicola Vinti*.* Fish-remains.

While examining the cores from the bore-hole at Thurgarton, near Nottingham, MR. GIBSON has made an important observation. He has found that the marls with *Productus horridus* rest on some red sandstones, identical in lithological character with the Keele Sandstone. The base of the Permian marls is a breccia, suggestive of a break between the Zechstein and Red Sandstone and Marls. Plant-remains are common at one horizon among the red sandstone and marls in the bore, and some of them have been sent to MR. KIDSTON for identification. The red sandstones have a dark calcareous shale with *Entomostraca* at their base, and are underlain by grey measures resembling the sandstones and shales of the Newcastle-under-Lyme Series. This is confirmed by the occurrence below these grey measures of mottled red marls, containing thin bands of coarse green grits like those so characteristic of the Etruria Marl Series in North Staffordshire. These red marls at Thurgarton pass down into grey measures containing Coal-seams. The recognition therefore of the divisions into which the Upper Coal-measures of North Staffordshire can be divided has thus great economical importance, as it enables us to detect the coal-bearing strata, and to fix their stratigraphical position under the Permian and younger formations of the centre of England.

Cheshire.

Macclesfield
District. (Mr.
Pocock.)

In order to complete the one-inch map which contains the northern part of the North Staffordshire Coal-field (No. 110) it has been necessary to revise the ground that stretches northward into Cheshire. Accordingly MR. POCKOCK was stationed at Macclesfield with instructions to revise the Carboniferous tract to the east of that town. The district, which during the past year has been examined by him, lies between Macclesfield and the articial fault described by the late PROF. GREEN as running in a north and south direction, four miles further east.

The general structure of the ground has been well described by PROF. HULL and PROF. GREEN in their Memoir "On the Geology of Stockport, Macclesfield, Congleton, and Leek," but

* Dr. Wheelton Hind. *Quart. Journ. Geol. Soc.*, vol. lv. (1889), p. 367.

some modifications of detail have been found necessary, in order to bring the mapping into harmony with the revised ground further south. The outlier of the fifth Grit, represented on the published map to the north-west of Forest Chapel, and the band of the same rock between Walker Barn and Tup Close Farm proved, after careful examination, to form really one continuous outcrop with the Yoredale Grit immediately to the east. This outcrop is repeated by a set of cross faults, one with a northerly trend, and the other pointing a little north of east. Half a mile west of Forest Chapel the strata arch over to the west, and the same grit appears with a westerly dip, succeeded by another, which crops out on the edge of Langley reservoir. The latter band is referred to in the Memoir as the Yoredale Grit, but is not shown on the published map. A mile further west, the escarpment of Tugg's Nose, which rises abruptly 550 feet above the valley, clearly represents three grits, and not merely the third and fourth, as shown on the map. The succession between this place and Forest Chapel, as well as on the west side, is complicated by faults. The belts of shale separating the different members of the grit series appear to be faulted out on the high ground east of Macclesfield, though they can be seen in the deep brook-sections to the north.

ld
Macclesfield
District. (M
Pocock.)

South Wales.

During the past year the field-work in South Wales has lain chiefly in the region between Swansea and the northern edge of the coal-field (Sheets 230 and 247), but has included also the eastern part of the Gower peninsula, and a small tract near Bridgend (Sheet 262). MR. TIDDEMAN, having completed the area assigned to him at Bridgend, commenced the examination of the Limestone and Coal-measures of Gower. MR. STRAHAN surveyed the ground east of the Tawe from Swansea to Ystalyfera, and part of the north crop, while MR. CANTRILL carried on the examination of the north crop, and of the Millstone Grit and Limestone beyond it. MR. GIBSON was engaged for a short time in completing an area near Neath, upon which he had been engaged before his transference to Staffordshire.

S. Wales.
(Mr.
Strahan.)

The following account of the past season's work of the staff in South Wales has been drawn up by MR. STRAHAN, to whom his colleagues have supplied notes regarding the ground surveyed by them.

Carboniferous Limestone.—The limestones of Gower are described by MR. TIDDEMAN, so far as his investigations have gone, as being similar to those of the anticline between Cowbridge, Bridgend, and Porthcawl. They consist chiefly of grey rock, more often dark than light, with also shades of buff. Some of the oolitic bands weather white. Crinoidal limestones are not common among them. The greater part of the rock consists of fine current-bedded organic *débris*. Another common type shows an almost black stone, containing small organisms and

S. Wales.
(Mr. Tidde-
man.)

larger nests of white crystals, which may represent the remains of shells or corals. The oolitic limestones range in tint from almost black to nearly cream colour.

A curious set of limestones occurs along the north side of Mumbles Head. There are at least three which assume the appearance of a breccia. But the fact that the interstices between the apparent fragments are sometimes occupied by dolomite suggests that the rock is not a true breccia, but has been dolomitised along cracks. The surfaces of some other bands are marked with a number of small pits, most of which contain an irregular nodule, also apparently of dolomite. The edges of these pits frequently rise above the surrounding surface, as though there had been some obstacle to regular deposition. Similar strata were noticed by MR. TIDDEMAN at Newton Nottago, fourteen miles to the east of Mumbles.

A limestone known as "Black Lias," which forms a rampart-like scarp on the seaside of Oystermouth Castle, closely resembles the normal form of Lower Lias, but contains Carboniferous fossils. It is used for building and road-metal, and will make cement. It is black, but becomes coated with a fine white powder on exposure to weather. Occasionally, between strong joints, the stone has decayed to a kind of rotten stone, and MR. TIDDEMAN suggests that it may be represented by some white clays with *Fenestella* and casts of crinoids, and some thin bands of disintegrated chert, which crop out further west. The clay was formerly worked at the Croft on Langland Road, on the opposite side of the glen, and south of Newton.

The general structure of the area of Carboniferous Limestone in Gower may be described as that of a great compound anticline, striking generally W. 16° N., and broadening to the west, where eventually the Old Red Sandstone comes to the surface. The anticline is crossed by many small faults, ranging from north-north-west to N. 10° E. in direction, but it is also greatly folded and traversed by faults which run along the strike, and even coincide for long distances with the bedding, only here and there showing their true nature by a slight transgression. Notable instances where the beds are nearly vertical, and where evidently a fault strikes along a compound anticline, occur at Three Cliffs Bay and Sheer Cwm.

One of the largest folds of the compound anticline is that of Oystermouth, which is enclosed between the main mass of the limestone of the Mumbles Head and the road to Newton. The soft strata overlying the limestone are let in here. A fault running nearly along the road brings up to the north the limestone on which Oystermouth Castle stands. On the south side the boundary is probably natural, but the strata are vertical. Much of the Gower limestone has undergone dolomitisation, a change of composition for the investigation of which the services of a chemist were needed. DR. POLLARD was accordingly instructed to make a careful examination of the extent and mode of occurrence of the dolomitisation, and to collect such specimens as might be necessary for analysis. So far as the observations

have gone at present, MR. TIDDEMAN infers that all the limestones are liable to the change; that the alteration takes place along both planes of bedding and faults; that it occurs at all elevations, but apparently reaches its greatest development low down by the sea. S. Wales.
(Mr.
Cantrill.)

The Carboniferous Limestone of the neighbourhood of Cowbridge, the surveying of which has now been completed by MR. CANTRILL, forms part of the Cowbridge-Cardiff anticline. The shales which underlie the main mass of the limestone appear to crop out in the bottom of the valley of the Dawen, while the overlying rock forms the precipitous western side. The greater part of the main limestone is concealed under Secondary rocks, but it seems to consist in the lower part of dark crinoidal limestone, succeeded upwards by light-coloured oolite.

In the north crop MR. CANTRILL has continued for some miles the tracing of the highest subdivision of the series, namely some shales with their black limestones. The rotten-stone, into which the limestones weather at the outcrop, becomes less pure westwards, and the whole band grows less important, but the workings have been continued, wherever the outcrop is sufficiently free from drift or grit *débris*.

Millstone Grit.—The pebbly conglomerate which forms the lower part of the Millstone Grit of the north crop continues to be well developed as far westwards as the field-work has been carried. Its rugged grit-scarps are excellently shown on the eastern side of the Twrch Valley at Tyle Garw, and here may be seen, not far from its base, a thin band of black pyritous shale with thin black limestones containing brachiopoda. The rock has at times decomposed into loose *débris*, apparently through the dissolving out of a siliceous cement. This incoherent or friable material has been dug for silica for lining steel furnaces, and the Black Mountain Company is now quarrying a bed of soft grit for the same purpose. Hard unweathered grit is also ground up and used for the same purpose, the multitude of boulders in the bed of the Twrch being thus turned to account.

The middle or shaly portion of the Millstone Grit, exposed in several of the moorland ravines, passes up into a set of thin impersistent sandstones with shales, which form a poor representative of the Farewell Rock. The line of division between the Millstone Grit and Coal-measures is purely arbitrary.

The strata lying next above the Carboniferous Limestone of Gower consist of black, thinly-bedded shales with *Posidonomya*, *Goniatites*, *Euomphalus*, &c. These were shown in the original edition of the map as Coal-measures, but they more nearly resemble shales associated with the Millstone Grit. To this formation also may be probably assigned some hard olive-coloured sandstones and shales, with some siliceous rootbeds which crop out near Liliput. The siliceous bands, which are not unlike Cockshot rocks, were proved by DE LA BECHE to be the floors of thin coal-seams.

Coal-measures.—The examination of the Coal-measures has been continued as far west as Cwm Llynfell on the north cr

S. Wales.
(Mr.
Strahan.)

and up to the east side of the Tawe between Pontardawe and Swansea. The surveying of the Cwmauon district having been completed, that of the Coal-measures which traverse Gower has been commenced.

In the north crop, where MR. STRAHAN was engaged with MR. CANTRILL in tracing the outcrops of the lower seams, the disturbances which have been already alluded to* acquire special importance from the fact that they here affect the lower portion of the Coal-measures. Not only are the seams over-folded and over-thrust, but the whole mass of sedimentary material has undergone deformation. The few shaft-sections which are obtainable do not therefore give the normal distances between the seams, and we have to rely upon estimates obtained by averaging data collected over a considerable area. The following table is based upon the consideration of a number of workings extending from Ystradgynlais to Gwaun-cae-gurwen:—

COMPARATIVE SECTIONS ALONG THE NORTH CROP, FROM
GARNANT TO THE VALE OF NEATH.

—	Garnant and Brynamman.	Ystradgynlais and neighbour- hood.	Dulais and Neath Valleys.
	Yards.	Yards.	Yards.
Stwrain Coal Measures - -	10	—	15
White Vein Measures - -	5 to 9	8	Upper or White Four-Foot Vein.
Black Vein Measures - -	22†	21†	
Little or Four-Foot Vein Measures - -	10 to 18	24†	19
Harnlo Vein Measures - -	19 to 22	25	Eighteen-Foot Vein 15 Cornish Vein. 13 Harnlo Vein. 11
Big Vein Measures with a Black Vein -	34 to 45	28 to 20	
Brass Vein Measures - -	18	19	Nine-Foot Vein. 20 Yard Vein. 21
Trigloin Vein Measures with Brynllloi, Little Brass, Middle, and Lower Veins	45 (supposed)	34 (supposed)	Two-Foot Vein. Measures with the Bluers, Enoch, Rhyd, and Grey (?Cnapiog)Veins, 78 (supposed).

All of these seams are anthracitic. The Four Feet or Little Vein, the Big, and the Brass, have been the most extensively worked. The first-named was raised principally in connection

* *Summary of Progress* for 1898, pp. 116-119.
† This figure is arrived at by averaging several sections.

with some noted ironstone, and is now scarcely being touched. The veins below the Brass Vein are worked in Cwm Twrch, but not further to the east. S. Wales.
(Mr.
Strahan.)

The disturbances take the form of acute folds which range in direction from about north-east at Cwm Llynfell to nearly east at Palleg. They thus cross the north-and-south system of normal faults almost at right angles. It seldom happens, however, that one of these "slip-faults" can be traced far in the disturbed ground. Sharp as many of the folds are, the coal has proved hard and workable both over the anticlines and down into the synclines, except on small strips upon the apices of the folds. Not infrequently the compression has reached a stage at which folding no longer sufficed to afford relief, and in such cases fracture ensued, and an overthrust or "overleaf" was produced. Many small and large examples of such structures may be examined in the old patch-works above Gyrnos, but one of the most instructive has been worked out in detail at the Palleg Colliery by MR. H. HUXHAM, from whose paper* the materials for the accompanying figure have been taken by his kind permission. The fold shown in the upper section is exposed to view in the precipitous side of the valley; in the second and third sections, which were drawn about 100 and 200 yards respectively further west, this fold has passed into an overthrust, which was fully explored in working the Brass Vein. The quantity of Brass Vein available was considerably increased by the overthrust, and the Big Vein, which had been previously worked, is said to have been thrice overthrust, so as to occur in three "overleaves," in this same ground.

To some such structure as this must be attributed a repetition of the outcrops at Ystradgynlais for which no explanation has hitherto been forthcoming. The Four Foot, Big, and Brass Veins crop out in the hillside between Ystradgynlais Colliery and the Hendre-ladis branch railway, with a steady dip to the south-east. Yet in the Giedd, more than half-a-mile to the north-west, where their position should be high in the air, these veins crop out a second time. The repetition would be accounted for by a fault running about south-west with a downthrow northwards of upwards of 200 yards, and it has been generally assumed that such a fault exists and runs under Ystrad-fawr, near the Hendre-ladis New Pit, by Penrhos and up the Tawe Valley to the Lamb and Flag Inn. This Cwm-ddu Fault, as it is called, must, however, be supposed to cross the outcrops of the Four Foot, Big, and Brass Veins near the Castle Inn, where there is no break in their continuity, while to the south-west it would range for a part of the Tawe Valley, where the crop of the Red Vein seems to disprove the existence of a fault of any magnitude.

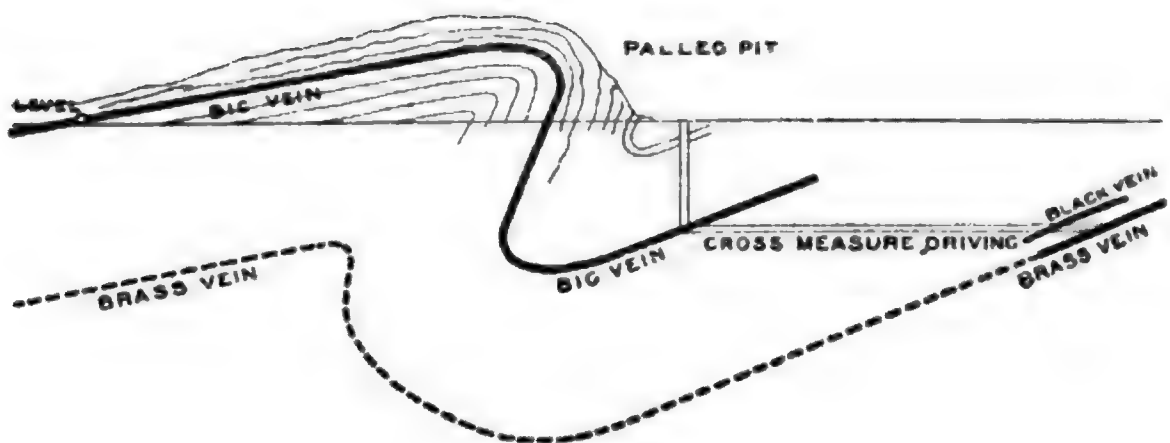
It would be impossible to describe in detail all the forms assumed by the strata in the disturbed belt of ground, but it may be mentioned that sharp folding may be seen in the old Cwm Phil patches; at Melin Palleg and in the Twrch Valley close by, as well as at the Palleg Colliery; in the Gwys Valley near Tir-y-gof;

* *Proc. South Wales Inst. Eng.*, vol. xx., p. 189, and vol. xxi., p. 2, 1898.

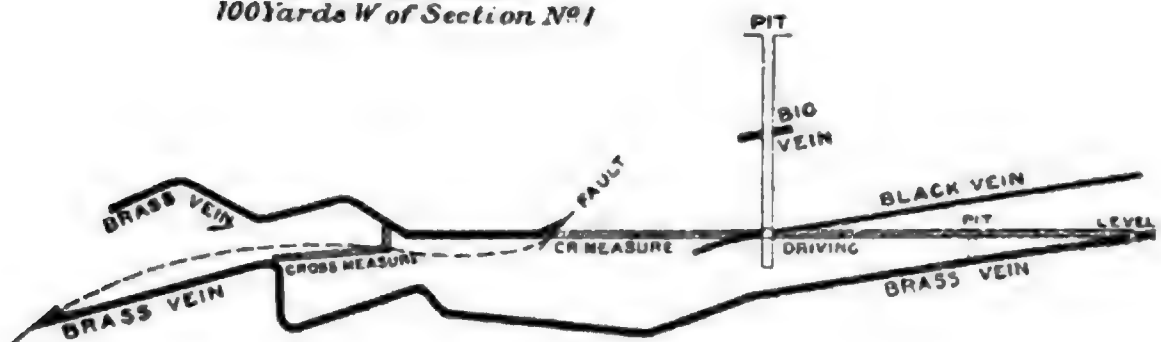
SECTIONS SHEWING THE PASSAGE OF THE PALLED MONOCLINE INTO THE BRYN MORGAN OVERTHRUST.

Re-drawn by permission from a paper by Mr H. Huxham
Proc. S. Wales Inst. Eng. Vol XX

SECTION N^o1 E. OF THE TWRCH



SECTION N^o2. W. OF THE TWRCH 100 Yards W of Section N^o1



SECTION N^o3. about 100 Yards W. of Section N^o2



0 100 200 300 400 500 600 FEET
SCALE — HORIZONTAL & VERTICAL.

in the Twrch Valley from Bryn Henllys to near the silica-works; S. Wales. and in Cwm Llynfell. Similar rolls occur in the old patch-works (Mr. Cantrill.) at Brynamman and in the Garw Valley, while some parallel disturbances have been noted by MR. CANTRILL in the Millstone Grit of Gareg-lwyd and Tair Carn.

The largest of the north-and-south faults which cross this part of the north crop is known as the Cwm Llynfell or Bryn-llefrith Fault. It is a downthrow to the west of about 240 yards, and falls into line with the Rhydding Fault so far as that has yet been traced. Another important fault crosses the Twrch river near the silica-works, and has been proved in the workings of the Brass Vein across the mountain to near the Gwys river. This also is a downthrow to the west, and forms the eastern limit of the field of the Brass Vein. Two important faults have been shown by MR. CANTRILL to throw down the trough of Millstone Grit which forms Esgair Hir.

The folding of the strata here described is almost wholly confined to the outcrop of the lower measures, and the Red Vein crops with great regularity round hill after hill. It would not be prudent, however, to assume that the lower strata are not similarly folded under those hills, for experience gained in other parts of the Coal-field has taught that soft measures of this type though highly contorted themselves may be directly overlain by strata in which no disturbance is manifest.*

The Red Vein, which is about $3\frac{1}{2}$ feet thick, lies about 170 yards above the Stwrain Vein, the highest of the seams mentioned in the table given above. It is worked at the Farteg Colliery, Ynysygeinon and Ystalyfera. At the Ynysygeinon Colliery it is thrown down westwards by two faults of forty and sixty yards respectively, one on each side of the level. The former dies away southwards, but the sixty-yard fault runs just east of Daren Wyddon and traverses the mountain for some distance. A branch of it with a westerly downthrow of about twenty yards is well seen in the southern angle of Daren Wyddon. The veins above the Red Vein consist in ascending order of the Welsh, the Pinchin and the Ynysarwed, none of which are at present worked in the area surveyed last year. The last-named represents No. 2 Rhondda, and lies at the foot of a conspicuous rock-feature; as at Crynant, there is a conglomerate band with pebbles of quartz and ironstone, a yard or two above the coal. The seam is visible in Daren Wyddon and Taren-y-gigfran, and it has been worked at the outcrop as far as Cwm Clic. In that ravine it has been recently driven into for about 200 yards, but being in troubled ground and the coal being a bastard-anthracite for which there was no good market, the workings were not profitable. The distance from the Ynysarwed Vein to the Red Vein can be calculated at the old pit at Ynysygeinon Junction. The Ynysarwed crops out 310 feet above the pit, and the Red Vein was reached in the pit at about 130 or 140 yards. Making

* *Summary of Progress for 1898*, p. 116.

S. Wales. allowance for the dip we get about 260 or 270 yards as the
(Mr. Strahan, distance between the veins, as compared with 270 yards in the
Mr. Gibson.) Dulais Valley.

Above the Ynysarwed, or No. 2 Rhondda, lies a great mass of almost unproductive measures, chiefly composed of Pennant Grit, with subordinate beds of shale, and a few bands of quartz-rock. This barren zone has hitherto proved a complete barrier between the productive upper measures of Swansea and those which have been described above. These productive upper measures may be considered to commence with the vein which is variously known as the Esgirn at Cwmavon, the Hughes Vein at Swansea, and the Wenallt at Neath and east of it, and the determination of the distance from the Ynysarwed to the Hughes Vein thus becomes of the greatest importance in view of the probability of deep explorations being carried out in the central parts of the Coal-field. An estimate therefore has been made from more than one source.

In the Neath Valley, the Clyne Shaft started 500 feet below the crop of the Wenallt Seam, and at a depth of 209 yards reached a coal, 2 ft. 10 in. thick, which was supposed to be No. 1 Rhondda. The crop of the Wenallt seam is 2,000 feet distant from the pit, and allowing a dip of 5° we get 434 yards as the true distance from the Ynysarwed to this supposed No 1 Rhondda. This distance, however, is too great, and the seam was probably No. 2 Rhondda, for in Cwm Cregen in the Cymmer Valley, MR. GIBSON finds the Wenallt to be 332 yards above No. 1 Rhondda, and 432 yards above No. 2 Rhondda. Again in the Cadoxton Pit, which starts twenty yards below the Gellia (Wenallt) Seam, and extends to a depth (including a borehole of 403½ feet) of 397 yards below that seam, no representative of No. 2 Rhondda has been found. Lastly a section has been plotted through Mynydd March Hywell, under which the Wenallt seam has been almost continuously worked under the name of the Gellia Vein* to the crop of the Ynysarwed Vein at Cwm Clic, with the result of showing that there must be not less than 420 yards of strata between the two veins. We may assume then that the actual distance from the Wenallt to the No. 2 Rhondda seam in the Tawe and Neath valleys lies between 420 and 440 yards.

The Wenallt or Hughes Vein is one of a group which has been extensively worked near Swansea. The group includes, in descending order, the Dirty, the Rhesog, the Slaty, the Curly, the Bodwr or Rotten, and the Hughes. Of these, one only exists in workable form at Neath and in the Tawe valley above Llansamlet, and whether that one represents the Hughes or the Bodwr is open to doubt.

The distance from the Graigola to the Hughes Seam has

* This seam is locally called the Graigola. During the past year, however, MR. STRAHAN has found that the true Graigola Vein lies about 230 yards higher up. A passage in last year's *Summary of Progress*, p. 115, in which the Graigola is correlated with the Wenallt requires modification. It is the so-called Graigola of Mynydd March Hywell which may be so correlated.

recently been proved by a shaft at Waun-y-coed near Pontardawe. S. Wales.
(Mr. Strahan.)
The sinking commenced 20 yards below the crop of the Graigola and proved the Hughes at 216 yards. Allowing for a small dip we may take 234 yards as the distance between the two seams.

From the Graigola upwards the section has been proved at the Dyffryn Main and Primrose Collieries. We may, therefore, proceed to construct a table showing the thicknesses of the measures of the Neath Trough, from the highest existent down to the lowest which may be inferred to exist from what can be seen at the North Crop.

		Thickness.		Depth below Bryn Coch Vein.	
		yds.	ft.	yds.	ft.
Bryn Coch Vein	- - - - -				
Measures	- - - - -	152	2	152	2
Wernffraith or Primrose Seam	- - - - -				
Measures about 105 yards	- - - - -				
Greenway or Court Herbert Seam, } at Dyffryn	impersistent - - - - -	226	0	378	2
Measures about 130 yards	- - - - -				
Little Tyr Edmond Seam	- - - - -				
Measures	- - - - -	2	0	380	2
Lower Tyr Edmond or Victoria Seam (the	- - - - -				
Hard and the Brithdir Vein)	- - - - -	25	2	406	1
Measures	- - - - -				
Graigola or Greenway Vein of Gnoll	- - - - -				
Measures, 37 yards	- - - - -				
Upper Maesmelyn Vein	- - - - -				
Measures, 50 yards	- - - - -	234	0	604	1
Lower Maesmelyn	- - - - -				
Measures	- - - - -				
Wenallt or Hughes Vein	- - - - -				
Measures	- - - - -	420	0	1,060	1
No. 2 Rhondda or Ynysarwed Vein	- - - - -				
Measures	- - - - - 260 to	270	0	1,330	1
Red Vein	- - - - -				
Measures	- - - - - about	200	0	1,530	1
Four Feet, Little, or Pencraig Vein	- - - - -				
Measures	- - - - - 33 to	40	0	1,570	1
Big Vein	- - - - -				
Measures from 20 to 45 yards	- - - - - say	35	0	1,605	1
Brass Vein	- - - - -				
Measures with Trigloin, Bryn-lloi, Middle,	- - - - -				
and Lower Veins	- - - - - about	100	0	1,755	1

It must be borne in mind that in this Table the measurements given for the strata below No. 2 Rhondda were obtained in the North Crop and that, in accordance with the general rule that the Coal-measures thicken southwards and westwards in South Wales, they would be considerably thicker under Neath. Further light may be thrown on the point when the South Crop has been more fully examined.

S. Wales.
(Mr.
Strahan)

The Neath section differs materially from that of East Glamorganshire. The No. 1 Llantwit, which may be taken to be the equivalent of the Mynyddislwyn of Monmouthshire, probably corresponds to the Wernffraith. Hughes Vein corresponds to the Wenallt, which, as was pointed out in the *Summary of Progress* for 1898 (p. 115), is probably the Pen-y-groes Vein of Llantwit Fardre. The Stwrain of Cwm Twrch is believed to be the Two Foot Nine Seam, while the Big Vein corresponds to the Nine Foot or Ras-las.

At Llantwit the No. 1 Llantwit lies 115 yards above the No. 3 Llantwit;* No. 3 Llantwit 60 yards above the Pen-y-groes Vein. At the Glyn Colliery the Tydu Vein, which is probably the Pen-y-groes Vein, may be estimated to lie about 270 yards above the No. 2 Rhondda, the distance between the two outcrops being 360 yards and the dip varying from 40° to 52° . The distance from the No. 2 Rhondda to the Two Foot Nine Seam has been proved in the Rhondda Valleys to average 300 yards, while in the same district the distance from the Two Foot Nine to the Big Vein ranges from 60 yards near Aberdare to 113 yards at Clydach Vale. We are thus able to construct the following comparative sections to illustrate the thickening of the measures in a horizontal distance of 20 to 25 miles. The most rapid expansion shows a rate of 1 in 116, which is by no means improbably great.

NEATH TROUGH.		RHONDDA VALLEYS AND LLANTWIT FARDRE.	
	Yards.		Yards.
Wernffraith Seam		Llantwit No. 1	
Measures 454 yards	488	Measures - - -	175
Graigola Seam			
Measures 234 yards in the Tawe Valley			
Hughes Vein		Tydu Vein	
Measures - - -	420	Measures - - -	270
Ynysarwed Vein		No. 2 Rhondda	
Measures - - -	440	Measures - - -	300
Stwrain Vein		Two Feet-Nine Seam	
Measures - - -	70 to 80	Measures - - -	60 to 113
Big Vein		Nine Feet Seam	
Measures - - -	20 to 35	Measures - - -	—
Brass Vein			

In the neighbourhood of Swansea only the Hughes and the veins above it are worked. The various seams are identifiable without much difficulty as far west as the Gardener's Fault, a downthrow of more than 300 yards to the west, which runs up Cwm Crymlyn by the Birchgrove Pit to Glais. The seams which are thrown in at Llansamlet on the west side of this fault are commonly stated to be bituminous, while those on the east are steam-coals, a statement which is true to the extent that, owing to the large displacement of the fault, seams belonging to the more highly bituminous upper part of the Coal-measures are thrown face to face with those belonging to a lower and more

* See Vertical Section of the Geological Survey Sheet, No. 81, section No. 6.

anthracitic zone. The correlation of the seams has been attended with some difficulty, partly owing to the fact that every shaft on the west of the fault has been sunk on a fault, and that for many years the true sequence of measures remained unknown, and partly in consequence of considerable changes undergone by the seams in that neighbourhood. The following table gives the most probable identification:—

LLANSAMLET (West of the Gardener's Fault).	Yds.	NEATH TROUGH (East of the Gardener's Fault).	Yds.
Drew's Vein		Bryn Coch Vein	
Measures - - -	165		152
Four Feet Seam		Wernffraith Vein	
Measures - - -	118		
Five Feet Seam			254
Measures - - -	118		
Six Feet Seam		Graigola Seam	
Measures - - -	20		
Three Feet Seam			
Measures - - -	44		
Two Feet Seam		Not proved, but about	240
Measures, including four or five workable seams in their lower part - - -	271		
Hughes Seam		Hughes Seam	

It would appear, therefore, that the Brithdir or Tyr Edmond Seam is absent on the west side of the fault, while, on the other hand, the group of seams which at Swansea occurs close above the Hughes Vein, is represented by one, or perhaps by two seams at Neath.

The surveying of the Bryn and Cwmafon district has now been completed by MR. TIDDEMAN. He finds that the strong rock-feature which he traced through much of the Maesteg district under the name of the Llynfi Rock is the same as that called the Tormynydd Rock further west. The Wernpystill Seam, which lies above that rock, and not the Tormynydd which lies below it, will therefore represent the No. 2 Rhondda Seam, which has been selected as the base of the Pennant series. The Cockshot Rock, another distinctive horizon, has been traced to the fore-shore near Baglan School.

The series of coal-seams below the representative of No. 2 Rhondda is as follows:—

The Tormynydd, which proves well from Cwmafon to Bryn.

The Jonah is thin throughout.

The White Seam is about 4 feet thick, and is regular from Cwmafon to Maesteg.

The Clay Seam proves well with a thickness of about 2 ft. 4 in.

The Cwm Mawr Seam is thick near Cwmafon, but thin from Bryn to Dyrysiog. It is considered to correspond to the Victoria Seam of Maesteg.

The Golden Vein has been worked by level from Cwmafon to Bryn collieries, and is about 3 feet thick. It is believed to correspond to the Two and a half Feet seam of Maesteg.

The Cockshot Seam rests upon or close above the Cockshot Rock and consists of two coals, 2 ft. and 2½ ft. thick. It represents the Caedefaid of the Llynfi, Ogmere, and Garw valleys

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The Finery Seam was formerly worked at Bryn on the anticline adjoining the Moel Gilau Fault, at Bryn Gyrnos and also at Cwmafon. It was much esteemed for copper-smelting.

This is followed in descending order by the Upper Four Feet, the Big Seam, the Coal and Mine Seam, the Lower Four Feet, the Four and Five Feet Seam and the Yard Seam, some of which have been worked about Cwmafon.

The Park Colliery Shaft at Baglan struck the Big Vein at 90 yards depth, but the ground was much disturbed owing to the nearness of the Moel Gilau Fault.

FAULTS.—*The Gnoll Fault.*—This great fault runs from the South Crop near Cwmafon to the Neath Valley near Llantwit by Neath. At Cwmafon it was proved in the working of the lower coals to be a downthrow to the west of about 70 yards, but at the Gnoll its throw must be between 400 and 500 yards, for at this point it brings the Court Herbert Seam nearly on a level with the Glyngwilym. Now the Court Herbert Seam is the Greenway Seam of Dyffryn, which lies 150 yards above the Graigola, and therefore about 390 yards above the Hughes or Wenallt. The Glyngwilym lies about 50 yards below the Wenallt, giving the total distance between the Court Herbert and Glyngwilym Seam as 440 yards.

The direction of the Gnoll Fault from Cwmafon to Gnoll is almost due north, but at the latter place it was proved in the workings of the Graigola Seam, and may be seen on the surface also, to turn to the north-west, the furthest point to which it has been proved being nearly under the Neath Workhouse. Its course from this point has been the subject of much dispute. It certainly does not cross the Gellia (Wenallt) workings of Cadoxton, and Mynydd March Hywell, nor can there be a large displacement if any between the Wenallt outcrops on the north and south sides of the Neath Valley. We are compelled to assume therefore that the Gnoll Fault must continue to head westwards so as to keep clear of the southernmost workings in the Gellia Vein, and must run into the Rhydding Fault. The bend is unusually abrupt for so large a fault, but can be matched to a certain extent both in the Rhydding and Dyffryn Faults further north. Moreover, it is a fact that the Rhydding Fault greatly increases in its throw at Cadoxton, as would happen if it had been joined by another large westerly downthrow, a fact, however, which is capable of another explanation.

The Rhydding Fault.—This fault is recognisable in the South Crop near Baglan House, and becomes an important downthrow to the west near Neath, its throw at Eaglesbush amounting to 140 yards. Near Cadoxton on the north side of the Neath Valley, it throws the Wernfiraith Seam nearly on a level with the Gellia, which means a displacement of about 500 yards, *i.e.*, an increase in throw of 360 yards in about a mile and a half. Two miles further north the throw increases to nearly 800 yards, but at Cwm Clic, nearly five miles north of Cadoxton, the fault throws No. 1 Rhondda on a level with the Graigola, which means a displacement of only about 340 yards. Thence the dislocation runs northwards and probably becomes the Bryn

Llefrith Fault previously mentioned. Two facts may be noted with respect to this fault. Firstly, it splits near Letty-sac so as to effect its throw by two steps; the easternmost step throwing in a small patch of the Graigola Vein (which is now being worked) on a level with the Gellia and being therefore about 240 yards, while the second step which lies between 300 and 400 yards further west, throws the Graigola down a further 500 yards, or more, to the position in which it has been worked at the Dyffryn Main Colliery. The second point is that the fault on approaching the Tawe Valley at Cwm Clic makes a sharp bend to the west, but after crossing the valley resumes its normal trend. The bend, though much less abrupt, resembles that made by the Gnoll Fault.

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The Dyffryn Fault, which runs nearly parallel to the Rhydding Fault, lies at an average distance of about a mile to the west of it. It is a downthrow to the east, and with the Rhydding Fault forms the well-marked trough of Dyffryn. It crosses the south crop on the west side of the Neath at Briton Ferry, and from Skewen can be traced northwards almost continuously both by old workings and on the surface past the Tawe Valley. This fault also on crossing that valley makes a bend similar to that made by the Rhydding Fault. At Skewen the Dyffryn Fault throws the Greenway down nearly on a level with the Graigola Seam, and may be taken to be a shift of 100 yards; near Dyffryn House it is believed to have a throw of 380 yards and at Wernddu of 440 yards, the Graigola of the west side being at a higher elevation than the Bryn Coch Vein of the east side. Here the fault is at its maximum, for near the Tawe Valley it throws the Graigola on the east a short distance only below the Hughes Vein on the West, a shift of less than 300 yards. Both here and at Llangiwig, however, it is accompanied by strong flexure which makes it difficult to estimate the shift effected by the fracture alone.

It will be seen that the Rhydding and Dyffryn Faults attain their maxima in the same region, namely near Bryn Coch; the measures dropped down in the trough between the two faults assume in fact a synclinal form, the deepest part lying at the spot named. The strata composing Mynydd March Hywell on the east side of the Rhydding Fault show no such synclinal structure, and the increase in the throw of the Rhydding Fault from Neath northwards is thought by some authorities to be sufficiently explained by the difference in inclination of the strata on its two sides, without the assistance of the Gnoll Fault, as discussed above. The supposition appears to involve a confusion between cause and effect; the synclinal form of the trough measures is the necessary result of so large a subsidence between two fractures of limited length.

The Gardener's Fault.—This important westerly downthrow runs from Jersey Marine by Glan-y-wern and up the Crymlyn Dingle. Here it throws the Llansamlet Four Foot Vein on a level with the Maes Melyn Vein. The Four Foot Vein we believe to be the Wernffraith, which lies 236 yards above the

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Graigola at Llansamlet, while the Maes Melyn lies about 87 yards below that vein, the throw of the fault therefore being 323 yards. The fault intersects the outcrop of the Graigola at the old Heol-ddu Colliery, and passes through the Birchgrove and Sister's Pits to Glais, whence its course is still under investigation.

The Brother's Fault.—This may be regarded as a branch of the Gardener's Fault, springing from it between Heol-ddu Drift and the Emily Pit. At the Brother's Pit it was found to consist of three steps of 40, 50, and 60 yards, all down to the west. It appears to have been touched from the Garth Pit and to range for the Midland Railway bridge at Clydach.

The Bethel or Parc Pit Fault.—This is also a downthrow to the west, and has been traced at present through Pentre-dwr, the New Pit and the Parc Pit at Trallwyn to the Gwern Pit. Here its throw is said to be 100 yards. The fault has been touched also in the workings both of the Drew's and Four Feet Seams from Brother's Pit, but its throw has not been determined, though it seems to be diminishing northwards. What may be a continuation of it was touched 200 yards south-west of the Garth Pit.

The Six Pit Fault traverses the pit of that name and the Marsh Pit, and is a downthrow to the west.

The Pwll Mawr Fault is a downthrow to the east of 80 yards at the Pwll Mawr Colliery, but is supposed to be rather less south of Bon-y-Maen. Its effects on the configuration of the ground are most marked, however, where it crosses the outcrops of the Hughes group of veins at Tir-isaf, and throws the soft measures associated with them against the Pennant of Carn Nicholas Farm. The fault runs out to sea at the Crown Spelter Works.

TRIASSIC.

As already mentioned, various tracts of formations younger than the Carboniferous series have been revised in connection with the resurvey of the Coal-fields, so that the one-inch sheets might be everywhere brought up to date. In North Staffordshire and the surrounding country this revision has been carried on by MESSRS. BARROW, GIBSON, POCKOCK, and WEDD. In South Wales the work has been mainly done by MR. TIDDEMAN and MR. CANTRILL.

North Staffordshire Region.

In North Staffordshire MR. BARROW has mapped two separate areas of Bunter Sandstone and Conglomerate. The first of these lies to the north of Leek, and forms the north end of the long inlier that fills the old pre-Triassic valley through which the Churnet now flows. This valley has been eroded in the mass of soft shales underlying the Third Grit. In shape it recalls the

form of some of the longer lakes of Scotland, from which, however, it essentially differs in that the water must have flowed out through the breaching of one side of the valley. This outflow not improbably occurred at the hollow south-west of Rudyard, as is suggested by the occurrence of the patch of Bunter at Endon, some miles down this lateral valley.

In the other or Cheadle area of Triassic rocks only their margins have been at present mapped, so that little can yet be said regarding them. Evidence has been accumulated as to the very uneven nature of the surface of the Carboniferous floor on which the Bunter strata rest. Thus, the mass of New Red Sandstone on the north side of Cheadle, shown on the published map as an outlier, resting apparently on a comparatively flat surface of Coal-measures, proves to be in reality merely the end of a thick mass that fills an old, steep-sided valley. This mass and the valley which it fills is continuous eastward to the Churnet valley, in which direction the water flowed. The breadth of this sandstone at Cheadle arises from the valley having here been cut out of soft shales. Further east the valley passes through the much harder Kingsley rock already referred to, and there, together with its infilling Bunter Sandstone, it becomes much narrower. This connection of the Cheadle outcrop with the main mass to the east is of considerable practical importance to the town of Cheadle, for instead of their water supply being obtained from a catchment area of only one square mile, it in reality taps the water that is accumulated in the great mass of sandstone to the south-east. The supply will thus be more than enough for the town for many years to come.

Cheadle District. (Mr. Barrow.)

To the west of Cheadle and in a direct line with the old valley just referred to, another ancient hollow existed which drained westward, and has likewise been filled up with Bunter Sandstone. Its position is indicated on the map by the tongue that projects eastward from the main outcrop of that rock. The coincidence in direction of these two valleys suggests a common origin for them. The southern end and side, and in some cases the northern, correspond approximately with a rather large fault in the Carboniferous rocks, whereby the position of the valley was probably determined. This influence on the topography dates from a time anterior to the deposition of Bunter strata, as the mining evidence clearly proves. While the Two Yard Coal has been met with on the upthrow side of the fault under the Bunter Sandstones, it does not exist in the bottom of the old valley, even although it has been thrown down 25 yards. After its dislocation and subsidence, this coal-seam was obviously eroded out of the bottom of the valley before the red sandstone was deposited. It has been further ascertained that when a small easterly or westerly projection of the Bunter Sandstone is met with, it fills a small steep-sided pre-Triassic valley, whether or not a fault may there traverse the Carboniferous rocks.

Nearly all the faults in the Cheadle coal-field are of pre-Triassic age; they all trend either due east and west, or north and south. No such faults have been met with in the Bunter

series in this area. There are, however, a few faults in the red rocks. They are, in the main, parallel to the trend of the steep-sided old valleys. The absence of any such faults in the Coal-measures, so far as known, raises the question as to what extent these faults cut the Carboniferous rocks, or are restricted to the overlying Red Sandstones. It seems probable that the latter supposition is really true in at least a number of instances. The pitting of the pebbles in the conglomerate shows that a great amount of compression has taken place, and these faults may represent the subsidence upon contraction of the incoherent sands into the deep and steep-sided valleys. They may thus have been quite superficial movements.

Stoke-on-Trent and Crewe Districts. (Messrs. Pocock and Wedd.)

Considerable difficulty has been experienced in establishing satisfactory divisions for the Trias in the Stoke district. The Keuper basement-beds are not sharply marked off from the underlying Bunter division and overlying Waterstones, and the latter graduate up into the Red Marls. It is doubtful, indeed, if the basement-beds are really represented there. Three divisions can be roughly made out. The lowest constitutes the Bunter group, consisting of red false-bedded sandstones and pebbly sandstones, with bands of shingle at several horizons; the middle includes even-bedded brown and white sandstones passing up into thin flaggy, thin-bedded sandstones with marl; the upper consists of red marl, with occasional thin bands of white and red flags, (skerries).

In the tract round Fulford Mr. Pocock has found the Trias subdivisions to be feebly represented. Not only are the Upper and Lower Mottled Sandstones absent there, but the Keuper Sandstones, which form the dominant features of the landscape in the Cheshire hills, occupy a subordinate position along the flanks of the plateau of Bunter Conglomerate, nor is there any clear division between the basement sandstones and the Waterstones. Thin sandstones of the waterstone-type are found interstratified with the coarser basement-sandstones, and though they are more common in the upper part of this division, it is not practicable to separate them on the map.

The Keuper Sandstones extend for about a mile south of Fulford, but in the Hilderstone valley they are absent and the Keuper Marl rests directly on Bunter Conglomerate. In the Triassic areas surveyed by Mr. WEDD, between Market Drayton and Betley, the same difficulty has been encountered in accurately subdividing the Trias. The broad divisions of Bunter, Keuper building-stones, flaggy waterstones and red marl can be recognised. The red marl passes downwards by a gradual increase of sandy material into flaggy waterstones. These, again, in their lower part alternate with, and perhaps pass laterally into, soft false-bedded red sandstones and harder coarse white and brown building-stones, which are even-bedded in the west of the district, but are often markedly false-bedded at Blythe Bridge in the east. They sometimes contain a few pebbles, and it is often difficult to separate them from the Bunter group. This group in the ground mapped last year consists, as elsewhere, of red sandstone and

pebble-beds, but it is uncertain whether these two types occupy separate horizons. At Merelake Hall, near Alsager, the Bunter group contains a considerable quantity of barium-sulphate as a cement, and narrow veins of baryto-celestite also occur. Barium is frequently found in the Keuper Sandstones of the western part of the district. Stoke-on-Trent and Crewe Districts. (Messrs. Pocock and Wedd.)

At Linleywood, near Talke, a small triangular patch has been represented as Coal-measures upon the published map, on the down throw side of the Red-Rock-fault, two faults being introduced to account for its unusual position. This patch, however, seems to be really Keuper Sandstone. It closely resembles the Keuper Sandstone of Beeston Castle in Cheshire, and that of Bearstone, near Norton in Hales. The rock seen in Linleywood passes up into red flaggy sandstones, and on the same strike in an adjoining field red flaggy waterstones are exposed. Moreover, a minimum thickness of some 400 feet of Bunter strata has been proved in the workings of Bunkers Hill Colliery only about 200 or 300 yards to the south-west.

South Wales.

Of the eastern half of the broad tract of Secondary Rocks which extends from Cardiff to Porthcawl some account has been given in previous reports of the work of the Survey.* The western half has now been completed by MR. TIDDEMAN and MR. CANTRILL, under the supervision of MR. STRAHAN, who, from the reports supplied by his colleagues and from his own notes, has supplied the following general statement:—

The description of the Secondary Rocks extending from Cowbridge to Pyle was held over last year until the examination of the whole tract had been completed. All the strata in this part of the region, especially the Rhætic, assume so abnormal an aspect and change so rapidly in lithological character that only by continuous mapping could the change be realised and the stratigraphical horizons be identified. The eastern part of the district was surveyed by MR. CANTRILL, and the ground from Pen-llin westwards by MR. TIDDEMAN. In company with these two officers a complete traverse of the district was made by MR. WOODWARD and MR. STRAHAN for the purpose of checking as far as possible the correctness of the identification of the Rhætic strata in their abnormal form.

Triassic and Rhætic.—The Triassic conglomerate at Llanharry was found by MR. CANTRILL to lie unconformably upon Carboniferous Limestone, Millstone Grit, and Coal-measures. It seems to be of Upper Keuper age, and earlier than the uppermost green marls. It usually consists of a mass of pebbles of Carboniferous Limestone (ranging up to two feet in length), chert, and grit possibly derived from the Old Red Sandstone. These

* *Annual Report* for 1896, pp. 66-68; *Summary of Progress* for 1897, pp. 125, 126; *Id.* for 1898, p. 138.

materials are embedded in a ferruginous calcareous matrix in which iron occasionally so far predominates as to yield an ore which has been extensively worked.

It has been shown in previous *Reports* that all horizons of the Keuper Marl assume a littoral character in one place or another. At Penarth there is a considerable thickness of normal red marl, at the base only of which any conglomerate occurs; at Pendoylan the upper part also becomes littoral, while at Bonvilston, Llantrithyd, and St. Hilary the overlying green marls also pass into breccias. At Llandough the lower parts of the Triassic breccia are red, while the upper are yellow and evidently belong to the time of the green marls. In spite of these repeated evidences of the neighbourhood of a shore-line, the Keuper Marls on the whole preserve their typical aspect as far west as they extend. The green marls are well shown in a clay-pit near Pencoed, three miles north-east of Bridgend, behind the Old Pyle Inn, and to the south and south-west of Pyle Station. In these sections they present no essential difference from the green marls of the Penarth region, though the Rhætic strata above them have assumed a totally new aspect.

RHÆTIC BEDS.

South Wales.
(Messrs.
Tiddeman
and Cantrill.)

The remarkable change which affects the Rhætic strata between Cowbridge and Pyle consists in the replacement of shales by sandstones and coarse grits, together with some increase in thickness. The thin group of soft shales and thin limestones which constitutes the formation at Penarth passes gradually into a massive rock which occasionally produces a moorland scenery rivalling that of the Millstone Grit. The change sets in near Cowbridge, but it is more fully developed near Bridgend and Pyle in the area surveyed by MR. TIDDEMAN. Its first appearance in the neighbourhood of Cowbridge is thus described by MR. CANTRILL:—

The lithological type as presented by the Rhætic rocks at Penarth persists for some ten miles westwards. At several points, even where they overlap the Keuper and rest directly upon the Carboniferous Limestone, the black *Avicula*-shales and the White Lias preserve their normal aspect, and manifest none of the signs of littoral deposition which usually characterise the Keuper under such conditions. Thus a roadside section near Bonvilston shows clays and thin *Pecten*-limestones resting directly on the Limestone.

Two railway-cuttings near St. Mary Church Road Station reveal a few feet of the upper Rhætic strata under the *Ostrea*-beds of the Lias. One bed, which is exposed for eight feet, is oolitic, an unusual feature in Rhætic limestone, and one not previously observed. In the cutting south of Cowbridge Station, limestones of Rhætic age, but not richly fossiliferous, with a few inches of breccia, probably of Keuper age, rest unconformably upon Carboniferous Limestone. They are overlain by a very

hard Liassic limestone, containing bands of the shelly rock known as Sutton Stone, which seems to be a modified representative of the *Ostrea*-beds. South Wales.
(Messrs.
Tiddeman
and Cantrill.)

At Tregyff, near Llantrithyd, the sandy type of Rhætic first appears. The *Avicula contorta* series is there represented by blue sandy marls with *Pecten*-limestone and a conglomerate containing pebbles of Carboniferous Limestone and chert, overlying sandstone with casts of *Cardium* and *Avicula contorta*. Similar sandstones prevail north of Tregyff and are associated with bands of limestone composed of shell-fragments and resembling the Sutton Stone variety of the Lias. The proportion of sandy material increases northwards towards the Carboniferous ground, and the Rhætic sandstones have been quarried near Cowbridge, at St. Hilary, and at Llandough.

At Pencoed, from which point westwards this account is founded mainly on notes by MR. TIDDEMAN, the Rhætic sandstones are let down between two faults. They are extensively worked for building, and have been used for silica firebricks. The rock is a rather fine freestone, white but with bands of a light greenish hue. *Pullastra arenicola* and scales of *Gyrolepis Alberti* have been collected from this sandstone. The presence of these fossils taken in connection with their superposition upon the uppermost green Keuper Marls exposed in characteristic form close by, as mentioned above, proves that the rocks belong to the *Avicula contorta* zone.

Near the top of the hill of Coed Mwstwr there is a small faulted outlier of this sandstone, together with yellow and green limestone-conglomerate which may represent the green marls under shore-conditions.

In approaching St. Mary Hill from Coychurch we pass over in descending order the *Ostrea*-beds of the Lower Lias, some compact limestone, which no doubt represents the Cotham Stone, some green marls with what appears to be an interbedded red marl, Rhætic sandstone, a space probably marking the outcrop of the Keuper green marls, and Keuper conglomerate. The sandstone at the brow of the hill has yielded to MR. TIDDEMAN obscure casts of mollusca and scales of *Gyrolepis Alberti*. St. Mary Hill Down, which is covered with huge blocks of Rhætic sandstone, is formed by a compound anticline, much broken by strike-faults. Towards the south, where the sandstone dips away to the lower ground, the edge of the moor is followed by a depression, probably marking the outcrop of the upper part of the Rhætic group, and this by an escarpment of the *Ostrea*-beds of the Lias. These beds, however, are not quite of their usual type, and close by pass into a beach of shore-deposits.

In Coity a road-section west of the Castle exposes alternations of these sandstones and shales with greenish colouring and a little red mottling. The strata at first sight much resemble Keuper, but yield *Modiola minima* in abundance, a fossil which is plentiful in the upper part of the Rhætic group.

South Wales.
(Mr. Tidde-
man.)

In the well-known Quarella quarries, where a white and pale-green building-stone is obtained, MR. TIDDEMAN has noted the following section:—

		Ft. in.
Rhaetic Beds	Blue limestone, with <i>Ostrea liassica</i> - -	0 2
	Clayey limestone, representing the Cotham Stone, variable.	
	Grey and green clay, with variable calcareous bands. <i>Lima</i> sp. - - - -	2 6
	White and pale-green sandstone, seen to -	35 0

The same rock was formerly quarried near the Angelstown Asylum, and Rhaetic fossils may be obtained in the quarry rubbish.

The railway-section at Cwrt Coleman, which was described in detail by MR. TAWNEY in 1865,* is now partly obscured, but some of the beds, to which he refers as containing fish-remains on the south side, can now be seen on the north side of the line. A field-road south of Melin Cwew shows a succession differing somewhat from that in the railway. We here obtain in descending order:—

Rhaetic Beds	Blue limestone with <i>Ostrea liassica</i> , <i>Pleuromya crowcombeia</i> , and a coral.	
	Buff marlstone, weathering white, probably representing the Cotham Stone.	
	Green marls with a band of red marl, closely resembling Keuper Marl.	
	Calcareous sandstone, several feet thick. Tough tufaceous limestone.	

The strata exposed in the railway-cutting on the north side of the line evidently rise from below these, and themselves rest upon the thick Rhaetic sandstone which forms the crest of the hill of Cwrt Coleman. The road-section therefore confirms the observation made in Coity that there is red and green marl associated with the upper part of the Rhaetic group.

Higher up the valley some old pits show black shales resting on green limestone and white marly limestone. The green limestone is full of shells, which however cannot be broken out, but there is little doubt that the strata belong to the upper part of the Rhaetic series.

The "Pyle Inn" quarry, which has been opened of late years to get stone for railway-viaducts, &c., gives the following sections:—

	Ft. in.
Sandstone with <i>Natica pylensis</i> , <i>Cylindrites oviformis</i> , <i>Myophoria</i> - - - -	12 0
Ochreous bed - - - - -	0 4
Fine sand - - - - -	1 3
Green and grey clay - - - - -	3 6
Calcareous nodular bed, <i>Acrodus minimus</i> - -	0 3
Shales - - - - -	1 3
Calcareous nodular bed, with fish-remains - -	0 3
Shales - - - - -	1 8
Fine whitish sandstone, with plants and at top a seam of quartz pebbles, with remains of <i>Hybodus</i> and <i>Acrodus</i> , seen to - -	12 0

* Quart. Journ. Geol. Soc., vol. xxii., p. 70.

The slopes below expose characteristic Keuper green marls. South Wales.

The Rhætic sandstone has also been much quarried west of Pyle Church, the outcrop being followed for a considerable distance. Near the entrance to the quarries a white sandstone is seen with casts of *Pullastra arenicola* near its base. Above it was a band of green and red marl of typical Keuper aspect. Further on in the quarry the sandstone, where it has been more lately worked, shows bright green marly partings with ripplemarks, and yields *Anatina præcursor*, *Myophoria*, *Axinus cloacina*, while *Natica* has been obtained from the quarry-rubbish. The occurrence of the red and green marls next above this sandstone suggests that that rock lies high in the Rhætic group, and probably corresponds to the upper of the two sandstones in the "Pyle Inn" quarry, which also yielded *Natica*, etc. (Mr. Tidde-
man.)

Of the many scattered openings on Stormy Down the greater number have been made in search of sand for silica-bricks. One of these, lying south-west of the works, shows about 20 feet of massive sandstone, much like a Carboniferous sandstone, but resting on and containing thin seams of green clay. A little further west a swallow-hole shows that below it lies a limestone devoid of organisms and apparently of chemical origin, which is probably Keuper. The sandstone is thought by MR. TIDDEMAN to represent the lower sandstone of the "Pyle Inn" quarry. Further east, sandstones with green and yellow clays are exposed in a long line of excavations. They are occasionally green and ripple-marked, and yield casts of *Avicula contorta*. These probably represent the upper sandstone of "Pyle Inn" quarry.

The "Little Cement Quarry" on the edge of the Down, south-south-east of the Stormy works, shows a bed of shelly white limestone, resembling those seen in the old Rhætic pits west of Cwrt Coleman. From the material thrown out in deepening a spring close by, MR. TIDDEMAN obtained *Natica pylensis*, *Myophoria* sp., and *Cylindrites oviformis*.

The thick Rhætic sandstones form an escarpment of coarse white and yellow conglomerate near the top of Stormy Down. On some of the big blocks casts of lamellibranchs may be seen, but in other respects the stone might be taken for Millstone Grit. Such blocks are scattered all across the Down, and it was in one of these that the jaw of *Zanclodon cambrensis* was discovered.* It can now be stated with confidence that the *Zanclodon* occurred in true Rhætic strata of the zone of *Avicula contorta*.

In reference to the sections above described, MR. TIDDEMAN remarks that two points will strike anyone familiar with the typical aspects of Rhætic rocks in this country. One is the great preponderance of sandstone, the other is the occurrence of red beds above the sandstones, a colour which it is usual to associate with the Keuper Marl. From the abundance of sandstone he infers that the sediment was derived from a near source, probably the

* *Summary of Progress* for 1898, p. 202. See also E. T. NEWTON, *Quart. Journ. Geol. Soc.*, vol. liv., p. 646.

South Wales.
(Mr. Tidde-
man.)

sandstones of the Carboniferous or even of the Old Red Sandstone, while the remains of plants in them, and of land-reptiles such as the *Zanclodon*, to which we may perhaps add ganoid fishes, all point to an estuarine origin. The red beds suggest a land-locked area in which copious evaporation and chemical precipitation could go on. The silting up of an estuary might furnish some of the conditions necessary for the deposition of strata of this nature. The evidence shows that in the area around Bridgend in Glamorganshire, the Rhætic beds are intimately linked with the Keuper Marls. They exhibit, in fact, a local recurrence of the sedimentary conditions which attended the deposition of the Keuper Marls.

MR. TIDDEMAN believes further that it is not altogether impossible to recognise some of the limits of such an estuary as that in which these deposits may have been laid down. One fairly defined shore may be recognised at St. Mary Hill Down. It is generally, though not invariably, the case that where the upper Rhætic beds have been deposited, a normal succession can be traced up into the Lias, but that where the Lias is conglomeratic no Rhætic strata lie below. The presence of conglomerates in the Lias thus furnishes a clue to the original limits of the Rhætic area. Another point on the south side of the estuary can be fixed between Tythegston and Merthyr Mawr, where the Lias overlaps the Rhætic formation, and rests as a shore-deposit upon Carboniferous Limestone. The northern shore of the estuary is obscured by faulting, but the high ground of the Coal-field must certainly have formed an extreme limit in that direction. Near the southern side of the supposed estuary MR. TIDDEMAN notes that shell-banks, calcareous tufas, and sandstones permeated by carbonate of lime occur at points which are almost certainly near what were shores of Carboniferous Limestone. Coarse grits and sandstones containing quartz-pebbles prevail in the Rhætic series, near where the Millstone Grit no doubt forms the underlying rock.

Isle of Skye.

In the *Annual Report of the Geological Survey* for the year 1896 some particulars were given of the Passage-beds, which occur between the Lower Lias and the New Red rocks in Skye and Raasay. In Skye the strata, which comprise some six or eight feet of calcareous sandstones, limestones, and micaceous shales, are exposed in situations rather difficult of access, in the banks of Allt a' Mhuilinn, south-west of Broadford Free Church, at the cascade of Allt an Daraich, on the eastern side of Heast, and on the foreshore at Lusa (Lussay). These Passage-beds have been regarded by MR. H. B. WOODWARD as the only portion of the Secondary series of this region likely to be of Rhætic age, but he failed to find any recognizable fossils in them in Skye and Raasay, or at Applecross, in Ross-shire, where similar strata occur. Last summer MESSRS. A. MACCONO-

CHIE and DAVID TAIT were instructed to make a diligent search for fossils at the above-mentioned localities in Skye, and they were rewarded by the discovery of a number of fossils, which have been submitted to MR. E. T. NEWTON and DR. F. L. KITCHIN.

At Ob Lusa, about eight feet beneath the famous coral-bed, which rests on a band of *Ostrea*-limestone (Lower Lias), there were obtained *Pleuromya?* *Nerita?* and *Cerithium cf. semele*, d'Orb. At Heast there were found some doubtful plant remains, together with *Ostrea*, *Mytilus*, and a fish-scale. At Allt a' Mhuilinn a number of Lamellibranchs were found, some of which closely resemble the Rhætic form *Myacites Escheri*, figured by Dumortier.*

The fossils are poorly preserved and crushed, so that they cannot be satisfactorily determined. In the opinion of both MR. NEWTON and DR. KITCHIN all the forms are such as might be expected to occur in the Rhætic Beds, and MR. WOODWARD, who has collected from the Rhætic Beds in many localities, is of the same opinion.

Isle of Arran.†

The most important observation recently made by the Geological Survey in Scotland is the discovery of fossils of Rhætic age in a streamlet about a quarter of a mile to the north-east of Derenenach, above the String Road, five miles to the south-west of Brodick in the Island of Arran. The rocks there have been mapped by MR. GUNN, who found them to be considerably disturbed. It was at first thought that they might belong to some part of the Old Red Sandstone. But eventually MR. MACCONOCHIE found in them a series of fossils which left no doubt that some of them are Rhætic. The specimens were first submitted to MR. PEACH, who recognised such characteristic forms as *Avicula contorta*, *Pecten valoniensis*, and *Cardium rhæticum*. They were subsequently placed in the hands of MR. E. T. NEWTON, who has supplied the following note regarding them:—

Avicula contorta, Portl. Several specimens clearly referable to this species leave no doubt as to the beds from which they came being of Rhætic age.

Pecten valoniensis, Defr. Two or three fairly good specimens agree with the shells from Rhætic beds, which have been called *P. valoniensis*.

Schizodus (Arinus) cloacinus, Quenst. One or two examples of shells with a sharp posterior keel are believed to be this species.

* *Études Pal. sur les dépôts Jurassiques du Bassin du Rhone*, 1864, Plate I., figs. 5 and 6.

† The discovery of the fossils was made after this *Summary of Progress* had been sent to the printer. Subsequently as these pages were passing through the press, Mr. Peach and Mr. Gunn ascertained that the strata containing the Rhætic fossils are not *in situ*, but are enclosed in a coarse conglomerate that fills a volcanic vent, probably of Tertiary age. The same observers also found masses of limestone containing Lias fossils and fragments of chert containing *Foraminifera* which may possibly be Cretaceous.

Protocardium philippianum? Dunker (= *P. rhaticum*). There are two or three specimens which are in all probability *P. philippianum*, but none are so perfect as to make their identity certain.

Modiola minima? Sow. (= *minuta*, Goldf.). A specimen about $\frac{3}{4}$ in. long is referred to this species with some doubt.

Estheria minuta? Goldf. An imperfectly preserved impression of an oval shell may perhaps be this form, but it is very uncertain.

Gyrolepis Alberti? Ag. A broken fish scale showing a few ridges may be provisionally referred to this species.

The lithological characters of the strata containing the Rhætic fossils resemble those which are so persistent at the top of the Triassic system all through England and Wales. The red marls recall the well-known marls of the Keuper group; the grey marls seem to come in here as they do in South Wales, immediately below the fossiliferous black shales; and the latter again, though somewhat hardened, closely correspond with the equivalent strata in the same region. Fragments of decayed limestone which occur in the agglomerate have yielded what appear to be Lower Lias forms. They are not well preserved, but MR. NEWTON believes that they probably include such characteristic forms as *Ammonites angulatus* (?), *Cerithium semele* (?), *Gryphea arcuata* (?), *Pentacrinus basaltiformis* (?), and *Ditrupa globiceps*.

The importance of this fresh discovery in Arran is at least twofold. In the first place it probably gives a definite stratigraphical horizon for the red rocks of the southern half of the island, suggesting, if it does not absolutely prove, that these strata, in at least their upper portions, belong to the Keuper group, and are probably all of Triassic age. In the second place, the intrusive igneous rocks which disrupt these strata, and which form only a part of the great system of bosses and sills in the southern half of Arran, are now proved to be post-Liassic, or even post-Cretaceous, if the cherts should eventually prove to contain Cretaceous *Foraminifera*. Thus a further interesting and valuable piece of evidence is obtained to prove the comparatively late date of the younger igneous rocks of Arran.

JURASSIC.

Leicestershire and Rutland.

Hallaton and
Burrow-on-
the-Hill.
(Mr. Fox
Strangways).

The only tract of Jurassic rocks which has come within the range of the field-work of the Survey during 1899 lies to the east of the town of Leicester, on the borders of Leicestershire and Rutland, where MR. FOX STRANGWAYS has pushed the mapping eastward, so as to complete Sheet 156 (new series of the one-inch map). The district which he has so far completed lies between Burrow-on-the-Hill and Hallaton. It consists mainly of Upper and Middle Lias, with here and there thin coverings of Drift, which in a few places attain considerable importance. This part of the country was originally surveyed by PROFESSOR JUDD, but its revision on the six-inch scale allows considerably more detail to be put on

the maps, and shows that the boundaries that have been drawn on Sheet 64 (old series) are merely approximate. The chief alterations to the published map, so far as the revision has advanced, appear to be at Skeffington and Noseley, where the Middle Lias has been found to extend much further than was supposed. In the first case, the Middle Lias probably stretches along all the high ground from Tugby to Skeffington, as strata of this age have been found at the latter village. It is not seen in the intermediate area owing to the thick covering of Drift. On the western side of the large valley between Goadby and Noseley an extensive outlier of Middle Lias was entirely overlooked in the former survey. This mass probably reaches from Noseley to the west side of Illston, and thence north to the fault at Billesdon, but its component strata are only seen at Rolleston and Illston, the rest of the ground being thickly covered with Drift. This western extension of the Middle Lias somewhat modifies the published view as to the size of the Billesdon Fault,* which is probably not nearly as large as was supposed. Although there seems to be an east and west fault there, it is probably not of any great magnitude. The outcrop of the Middle Lias south of Goadby is also incorrectly shown on Sheet 64, the Drift not being nearly so thick as the map would lead one to suppose.

Hallaton and
Burrow-on-
the-Hill.
(Mr. Fox
Strangways.)

The principal topographical feature that attracts notice in this district is the striking tabular forms assumed by the Middle Lias and Inferior Oolite over all the country from Somerby to Billesdon. Further south the Middle Lias becomes much thinner, and except at Goadby, it is only obscurely seen peeping out here and there from beneath the Drift.

CRETACEOUS.

Hampshire, Wiltshire, and Dorset.

In the counties of Hants, Wilts, and Dorset a small Cretaceous area has been examined by MESSRS. REID and DIXON, but the whole of the Chalk within it belongs to the Upper division, and is similar to that found in the surrounding country. Though much of the upper part of the Chalk is missing in the Cranborne district, represented on Map 314, there is no clear evidence of irregular folding or tilting before the deposition of the Eocene strata. In the absence of marked beds it is difficult, however, to speak with confidence on this point, especially as the junction of the Chalk and Tertiary formations is usually much "piped" as well as eroded.

Sussex.

For the purpose of securing the early completion of Sheet 317, which embraces the district between Petworth and Chichester, Midhurst District.
(Mr. G. W. Lamplugh.)

* Geology of Rutland, *Mem. Geol. Survey*, p. 66.

Midhurst
District.
(Mr. G. W.
Lamplugh.)

the mapping of the Cretaceous rocks was assigned to MR. LAMPLUGH, who, during the summer and autumn, carried forward the revision from the margin of the ground previously mapped by MR. HAWKINS, two miles west of Midhurst, eastward to the transverse valley of the Arun at Pulborough. The strata above the Upper Greensand had already been surveyed by MR. CLEMENT REID, so that the work consisted in tracing on the six-inch Map the outcrops of the various divisions of the Lower Greensand, Gault and Upper Greensand, together with the superficial deposits by which they are in places overlain.

According to the classification of the original Survey Map, the uppermost portion of the clayey deposits which occur immediately beneath the Lower Greensand escarpment is supposed to represent the Atherfield Clay, though definite evidence on this point is rarely forthcoming. A few marine fossils were, however, found long ago in nodules from this clay at the brickyard at Harwood's Green, near Pulborough, which serve to differentiate it at this locality from the underlying Weald Clay of fresh-water origin; and MR. LAMPLUGH obtained some specimens from this place.

There are occasional indications that the clay becomes interstratified with silt and fine sand towards its junction with the overlying Hythe Beds, and that in passing southward the base of the latter strata may contain an increasing proportion of clay.

The broader grounds for the classification of the Lower Greensand into the supposed equivalents of the Hythe Beds, Sandgate Beds, and Folkestone Beds of East Kent, are readily grasped in this part of West Sussex, though the exact boundaries of the sub-divisions are usually more or less vague, seeing that they rest entirely upon lithological differences which are subject to much local variation. The Hythe Beds are characterized, as in Kent, by irregular calcareous stone-bands among half-indurated loamy glauconitic sand, with the local development of impersistent layers or concretions of chert. The calcareous sandstone has been much used for building, and the chert is extensively dug for road-mending.

The Sandgate Beds are variable in composition, but contain more clay and silt than the underlying and overlying divisions. In the western part of the district a thick bed of sand, near the base of this series, is partly composed of smooth polished grains of brown iron-ore. It has been suggested that this ferruginous sand might be of some economic value, but the average percentage of iron (23) is probably too low to bear the cost of carriage. The iron-sand disappears rather suddenly at a short distance to the eastward of Selham. The Sandgate Beds are for the most part destitute of fossils, but MR. LAMPLUGH found a richly fossiliferous band, consisting of ironstone crowded with the casts of marine shells, at the top of the iron-sand, in two apparently new localities near Midhurst (June Lane, and the river bank due south of Cowdray Ruins). In the stream-bed east of Ambersham Common, the same observer collected from a thin band of sandstone some plant remains, including traces of *Weichselia*.

The Folkestone Beds consist of sharp sand, strongly current-bedded, with ironstone concretions and thin partings of pipe-clay. Excepting the cast of a fragment of wood with teredo-like borings, no organic remains were found in these sands. At the top of this division, immediately below the Gault, the sand is indurated into a hard grit-band, from two to four inches thick, of a deep red colour, which is persistent throughout the area examined.

Midhurst
District.
(Mr. G. W.
Lamplugh.)

The Gault and Upper Greensand maintain the same character as in the country farther westward, and require no especial comment here. A few fragments of *Aminonites*, apparently *A. interruptus*, were collected in a brickyard in the Gault at Pitsham, near Midhurst, and the same species was also found in a new brickyard at Hardham. Both sections would probably yield better specimens if examined during the excavation of fresh clay.

Among the fossils collected by MR. LAMPLUGH during last season's work the following have been named in the Palæontological Department of the Survey by MR. E. T. NEWTON and DR. F. L. KITCHIN :—

JUNE LANE, MIDHURST, SUSSEX. (Sandy Ironstone ; Sandgate Beds.)

Cardium ?
Corbula striatula ? Sow.
Cytheræa ?
Nuculana scapha, d'Orb.
Tellina (*Linearia*), cf. *concentrica*, d'Orb.
Actæon sp.
Aporrhais sp.
Trochus ?

COWDRAY RUINS (RIVER BANK DUE SOUTH OF).
(Sandy Ironstone ; Sandgate Beds.)

Cucullæa sp.
Exogyra sinuata ? Sow.
Nuculana sp.
Trigonia sp. (of the group "*Scabræ*").
Actæon sp.
Cerithium ?
Trochus sp.

STREAM-BED SOUTH-EAST SIDE OF AMBERSHAM COMMON, 200 YARDS
NORTH-EAST OF HOYLE FARM. (Sandgate Beds.)

Cf. *Weichselia Mantelli*, Brongn.

HARWOOD GREEN BRICKYARD, NEAR PULBOROUGH, SUSSEX. (Nodules,
Atherfield Clay.)

Exogyra conica, Sow.
Pinna sp.
Thetis ?
Natica sp.

TERTIARY.

The revision of the Tertiary areas of the Hampshire and London Basins has been continued under the superintendence of MR. CLEMENT REID.

Hampshire Basin.

(Mr. Clement
Reid and Mr.
E. E. L.
Dixon.)

With regard to the ground already reported as re-surveyed, considerable progress has been made in the reduction and publication of the revised maps. The sheet of the map (No. 315), showing the country around Southampton, has been engraved and published during the past year. Sheet 316 (Fareham) is partly engraved; but has been kept back to allow of the insertion of information obtained during the progress of a new railway. The memoir on sheet 328 (Dorchester) has been revised and published. Sheet 314 (Ringwood), which it was hoped could be completed and engraved during the year, was delayed owing to the unexpectedly late appointment of Mr. DIXON, who only commenced work in July; and also owing to necessity of Mr. REID's presence at the office during part of the summer and again throughout December. The small area left over in this map (only about 14 square miles) will be finished early in the present year, and the map will then be sent to the engraver.

Hampshire has now been surveyed upon maps on the scale of six inches to a mile, with the exception of the north-east corner, around Aldershot. Half of Wiltshire has now been surveyed, mainly the eastern and south-eastern part. Dorset has advanced till about half the county has also been surveyed. In each of these counties the work of the past two years has consisted in completing and connecting scattered areas already partly mapped. The policy of completing defined areas will lead to the maps being more quickly available to the public, and ought to enable the work to be done more satisfactorily and more economically.

The recent field-work in the Hampshire Basin has been confined to the western border of the New Forest, the Avon Valley, and the adjoining parts of Dorset, all this ground being comprised in sheet 314. The area was almost entirely surveyed by Mr. REID, who mapped the Forest, the Avon Valley, and part of the Chalk in Dorset. The newly appointed Assistant Geologist, Mr. E. E. L. DIXON, was placed under Mr. REID's care, but as he only joined the staff in July, he could not contribute largely to the area of ground surveyed. He mapped the parts around Horton and Verwood. Much of Mr. REID's time in the field was necessarily spent in training his new colleague.

The scientific results of the past season's work in the Hampshire Basin have not been striking; for the area on which MESSRS. REID and DIXON were engaged was surrounded on every side by ground already carefully revised. In Hampshire Mr. REID found less than usual to alter in the Eocene boundaries of the published map (drawn by JOSHUA TRIMMER), and though there were a good many points of scientific interest, not much of economic value was found. The principal novelties were, the discovery that the mass of pebbly gravel on Ashley Heath (west of Ringwood) was of Eocene age, and corresponded to the shingle seen in the cliff east of Bournemouth. The irregular appearance

and disappearance of a mass of pebbles at the base of the marine Bracklesham Beds is not surprising; but it is noteworthy that on Ashley Heath this shingle is full of perfectly rounded pebbles of a peculiar siliceous sandstone, which corresponds exactly in its curiously waved bedding, and in the abundance of vertical root-cavities with the larger angular greywether blocks found loose, or in the Drift nearer to Salisbury Plain. In *Summaries* for previous years it has been shown that abundant evidence exists in the Hampshire Basin of an overlap westward and southward of the Reading Beds and of the Lower Bagshot group, till at last they rest on Palæozoic strata. We have now discovered evidence that the Bracklesham Beds also must overlap the lower horizons to a certain extent, for the pebbles of greywether must be derived from eroded strata of Reading age. A few fragments of Greensand-chert, which occur in the same pebble-bed, may have been derived from the chert-bearing fluviatile gravels of Bagshot or Reading age; they need not have been derived immediately from the Greensand.

(Mr. Clement
Reid and Mr.
E. E. L.
Dixon.)

New fossiliferous localities have been discovered in the Reading Beds, London Clay, Bagshot Sands, Bracklesham Beds, and Barton Clay; but within the area here alluded to fossils are badly preserved and not abundant. The most interesting change in the fossiliferous strata is the reappearance of a bed of marine fossils in the Woolwich and Reading series, this district being a long way from any other in which the Woolwich type, as distinguished from the Reading, is represented. The marine bed, already known through the labours of other observers, especially of MR. ERNEST WESTLAKE, occurs at Rockbourne, and from that place extends south-westward through Wiltshire. It has also been discovered by MR. DIXON at several new localities near Horton. The deposit is usually a glauconitic sand or loam, full of oysters, but containing little else. It now seems probable that the glauconitic loam without fossils, met with in the Dorchester sheet (No. 328) is a continuation of the same marine bed.

The Eocene deposits in the Dorset area surveyed last season are similar to those to the north-east and south-west. MR. DIXON, as just mentioned, has discovered some new fossiliferous localities in the Reading series, though the fluviatile deposits of that age still remain barren. It is interesting to note, however, that subangular gravels containing Greensand-chert and fragments of Palæozoic rocks make their appearance as far north-east as Downton, though they are scarcely so angular as they become nearer Dorchester. MR. DIXON has also obtained London Clay marine fossils at Verwood, and badly-preserved leaves in the Bagshot Sands not far from that place. He attempted to map out the clay-beds which often form marked features in the Bagshot series; but these proved to be as impersistent and irregular there as they are in other districts, and no one bed could be traced far. The clays dug around Verwood are not sufficiently good even for the coarse pottery there made, and the ware is consequently manufactured from the plastic clays of the Reading series, carted from other places.

LONDON BASIN.

(Mr. Clement
Reid and
Mr. A. C. G.
Cameron.)

A considerable area in Middlesex has been surveyed by MR. A. C. G. CAMERON during the past season under MR. REID'S supervision. The greater part of it is underlain by London Clay, seldom containing fossils, and of the ordinary type. During an inspection, however, of the Stanmore district, in company with MR. CAMERON, MR. REID was struck by the marked resemblance of the supposed "high-level Pleistocene gravel" to undoubted Eocene gravels in the Hampshire Basin, and to the pebble-beds exposed some years since at Highgate, in the grounds of St. Joseph's Retreat, and in the deep trench of the Steep-grade Tramway. The Highgate deposit certainly belongs to the top of the London Clay or to the base of the Bagshot Sands, and on closer examination it was found that the Stanmore gravel also presents all the characteristics of an Eocene deposit. Its flint-pebbles are nearly always well-rounded, they have undergone zonal alteration to the centre (Pleistocene alteration does not extend nearly so deep), and mingled with them are rare fragments of Greensand-chert, hard sandstone, black grit with quartz-veins, and a few quartz-pebbles. Their composition thus closely resembles that of Eocene gravels described in former *Summaries*.*

The unexpected result of this examination must lead to a reconsideration of the geological age of the whole of the supposed high-level Pleistocene gravels around London. It now seems doubtful whether outside the glaciated area any Plateau Gravels (*i.e.*, gravels more than about 150 feet above the Thames), are to be found that are not either of Eocene age, or derived wholly from Eocene deposits at a higher level. Stanmore is the highest hill (503 feet) in Middlesex, and dominates a considerable area down which the Eocene material has travelled.

Hungerford
District. (Mr.
J. H. Blake.)

At the western end or apex of the London basin, some fresh information has been obtained by MR. J. H. BLAKE as to the thickness of the Tertiary formations near Hungerford. It was derived from a boring made by MESSRS. CALLAS, SONS, and MAY in July last, at Kirby House, about a mile and a quarter east of Inkpen, and nearly two miles and a-half south of Kintbury. From specimens and detailed information supplied to him during the progress of boring, and from inspection of the material brought up at the place, MR. BLAKE was enabled to prove the occurrence and thickness of the following strata:—

	Feet.
Bagshot Beds - - - - -	90
London Clay - - - - -	52
Reading Beds - - - - -	75
To Chalk - - - - -	217
Chalk - - - - -	103
	320

* See for example *Summary* for 1897, p. 130. *Annual Report* for 1895, p. 11.

A well was dug to the depth of eleven feet, and the rest was bored. The clean-cut section of the well showed the Bagshot Beds to be well stratified, and to dip north at an angle of 26° . This steep inclination brings up the Upper Greensand from beneath the Chalk to form the "Shalbourn inlier," south-west of Inkpen, as shown on the Geological Survey Map. The information obtained by this boring, satisfactorily clears up what was previously obscure. The published maps show no Bagshot Beds at the site of this boring; the omission having perhaps arisen partly from a certain similarity of the variegated coloured sands and loams of the Bagshot Beds in this district, to those of the Reading Beds, and partly also from the absence of sections.

The Igneous Rocks of Skye.

The survey of the Tertiary igneous rocks of the Island of (Mr. A. Skye has been continued by MR. HARKER, who has been Harker.) engaged in the district of the Cuillin Hills and the surrounding parts of the great plateaux of basalt. He has prepared the following notes regarding his work of the past season.

The basaltic plateaux.—More than twenty square miles of the moorland country have been mapped, lying to the north-west, west, and south-west of the Cuillin Hills. The general nature of the ground is that of small plateaux or flat-topped hills, rarely reaching 1,500 feet above sea-level. The slopes are conspicuously terraced, the salient features being always due to the numerous hard intrusive sills intercalated among the softer lava-flows. The latter, in contrast with the sills, are in general amygdaloidal. The prevalent type is basalt not rich in olivine, graduating into rocks which might perhaps be more accurately styled augite-andesites, but no such discrimination has been found practicable in the field. Conspicuously porphyritic varieties occur in a few localities only, *e.g.*, below Coire Labain. Approaching the gabbro boundary at the foot of the mountains, the lavas become harder, in consequence of metamorphism, and, the intrusive sills at the same time dying out, the details of the surface-relief assume a new character.

The metamorphism imparts to the basaltic lavas a tougher consistency and a more splintery fracture. The attendant mineralogical changes are most evident in the amygdules, which here contain felspar (formed at the expense of zeolites), hornblende (from chloritic substances), quartz (from chalcedony), epidote, and other new-formed products.

Conglomerates, with subordinate banded tuffs, are interbedded among the basalts at several places on the slopes above Glenbrittle House and elsewhere, while breccias and agglomerates occur more frequently among those relics of the basalt group entangled in the gabbro of the mountains. The pebbles in the conglomerate are chiefly of Jurassic sandstones, well rounded, while basalt, gabbro, and granite occur more sparingly.

Isle of Skye.
(Mr. A.
Harker.)

The only place where the base of the basalt group has been reached in the course of the season's mapping is along the coast facing the Isle of Soay. The underlying rocks are here for the most part Torridonian (Applecross grit). The base of the volcanic group, which is about 400 feet above sea-level at the western point of Loch Seavaig, sinks gradually westward to only a little above high tide at the outlet of Allt nan Leac, the stream draining Coir' a' Ghrundda. Here a small strip of Lias limestones is exposed on the shore, while the Trias conglomerate, rising from beneath these limestones, forms a small promontory 200 yards east of the mouth of the stream, as recorded last year.* Farther west the basalts come down below sea-level. There is another locality within the area mapped where the base of the volcanic group must be very near the surface, viz., on the shore of Loch Harport, near Carhost. Some years ago piles were sunk for a new pier about 500 yards beyond the Talisker Distillery, and the cores preserved in the yard of the distillery are of sandstone, presumably Jurassic. It is stated that the borings were only six or seven feet deep, under ten feet of water at low tide (about twenty-one feet at high tide).

The gabbro of the Cuillins with its associated patches of basaltic lavas.—The survey of the Cuillin Hills has been nearly completed during the past season by the mapping of some nine or ten square miles of the main (western) range, with its subsidiary spurs. The detailed study of this part of the ground has brought out more clearly the complexity of its structure, and especially the very considerable part played by portions of the basaltic lavas entangled in the gabbro and highly metamorphosed. These enclosed patches have lenticular or less regular forms, with dimensions ranging from a few yards to more than a mile. When their inclination can be detected, it is usually found that they dip eastward, i.e., towards the interior of the mountains, agreeing generally in this respect with the other elements of the complex. The metamorphism is usually most intense in patches of small or moderate size, and the basalt thus indurated offers quite as much resistance to erosion as the gabbro itself, so that it occurs on the ridges rather than in the valleys. Some portions of these highly-altered lavas have a thoroughly coarse texture, and specimens would be unhesitatingly set down as gabbro, did they not still preserve relics of the characteristic amygdaloidal structure. This peculiarity may be taken as indicating that those rocks at least which exhibit it have not suffered bodily fusion in connection with the intrusion of the highly-heated gabbro; but the apparent gradual transitions from metamorphosed basalt to gabbro, though illusory, render the drawing of precise boundaries in some places a task of much difficulty. This difficulty is enhanced by another circumstance. It appears that the basaltic lavas so intimately associated with the large gabbro mass do not in general belong to the same part of the series as those developed on the adjacent moorland country.

* *Summary of Progress for 1898*, p. 137.

They are much less generally amygdaloidal, and what was there so distinctive a feature ceases to be available as a ready criterion on the more difficult ground. It is probable that in the northern and north-eastern parts of the Cuillins, mapped in former seasons, some rocks have been set down as intrusive diabases and fine-grained gabbros, which would be more correctly regarded as metamorphosed basaltic lavas. Isle of Skye.
(Mr. A.
Harker.)

Some of the central and highest mountains (such as those unnamed on the Ordnance map, but known to climbers as Sgùrr Alasdair, Sgùrr Tearlach, and Sgùrr Mhic Coinnich) consist in their upper parts almost wholly of basalt, with subordinate volcanic breccias, penetrated only by a few tongues of gabbro from below. From the extent and thickness of these lavas, they seem probably to be outliers of the rocks above the upper surface of the great gabbro laccolite, which, on this supposition, has a maximum thickness of about 3,000 feet or more.

The gabbro itself undoubtedly consists of numerous distinct intrusions in the form of wedges, sheets, and tongues, but their petrographical differences are not such as enable us to map them separately, even if the scale of the map permitted their delineation. An exception in this respect is the peculiar orange-crusted rock mentioned in the last report as remarkable for its extreme toughness, and for its containing innumerable xenoliths of a more normal gabbro. This rock occupies a considerable area in the western Cuillins, forming the peak at the junction of the Sgùrr Dubh ridge with the main range, and extending along the valley named An Garbhchoire. Here it is penetrated and enveloped by the normal coarse gabbro to the N.E., which is clearly of later date. On the other hand, the orange-crusted rock occurs at two places on the border of the gabbro area, viz., at An Sgùman and on the southern slope of Garsbheinn, and in both places is clearly posterior to the normal gabbro in contact with it. If the several masses of this peculiar rock are to be assigned to one epoch, we may draw the inference, on other grounds a likely one, that the normal gabbro on the border of the tract consolidated at a somewhat earlier time than that in the interior. Petrographical examination shows that the tough orange-weathering rock is of ultrabasic composition. It is usually a picrite, but passes into a pure olivine rock (dunite), and has also bands of troctolite associated with it.

Basic Dykes, Sills, and Sheets.—The intrusive rocks of the western part of the Cuillins and of the basalt country farther west are exclusively of basic (including sub-basic) composition. Acid dykes occur, as already recorded in the eastern part of the Cuillins, and occasionally on the moorlands to the north, but they do not extend westwards, a fact which tends to connect them genetically with the granite of the Red Hills to the east. It may be remarked too that granite veins in the gabbro, as well as independent acid intrusions, are wholly wanting in the western mountains; and even veins of pale felspathic gabbro, aplitic or pegmatoid, traversing the normal gabbro are comparatively rare except in a few places, such as the summit ridge of

Isle of Skye.
(Mr. A.
Harker.)

of Sgùrr Dearg. The most westerly independent intrusions of acid rock occur on the north-west slope of Sgùrr Thuilm, and consist of a biotite-bearing felsite—a type not elsewhere encountered.

As before, *basic dykes* were met with in great numbers on the ground mapped during the season. They are least numerous on the higher parts of the plateaux, formed by groups of thick sills. This may be due in part to the fact that some of the dykes supplied the material for individual sills and terminated at them; but the general explanation must be that the sills often presented an impenetrable barrier to dykes of later date than themselves. In many parts of the Cuillins the dykes are quite as numerous as on any portion of the basalt-ground. There are, however, in places considerable tracts of uniform coarse gabbro remarkable rather for the paucity of minor intrusions. Apparently some members of the complex body of gabbro have offered effective resistance to the passage of the dykes,

Comparing the dykes of the mountain district and the belt immediately surrounding it with those of the more distant parts of the basalt-country, and of Skye in general, we find a difference in their direction which seems to be of significance. In the basalt area the great majority of the dykes do not usually depart much from a direction north-north-west—south-south-east. In the mountains and the adjacent belt of country many of the dykes conform to the same law, but the general bearing has been governed by other factors, the principal group of dykes having a roughly radial disposition. They do not point accurately to a single central point, but the dominant set are so directed that, if produced, they would pass near the centre of the gabbro tract, or perhaps through one or other of several points situated within a central area. Further, the strong tendency of a dyke to run on in a straight line often causes it to be prolonged into a part of the tract where it makes an acute angle with the general direction in that place. In addition to the dominant radial set of dykes, there is a conjugate set approximately at right angles to them, the departure from rectangularity sometimes observed being due apparently to the same tendency to prolongation in straight lines. The conjugate set is usually subordinate to the radial, though locally it may attain almost equal importance. A noticeable hade is more frequent here than in the former set, especially in the outer belt of the tract, the inclination being very generally outward from the centre. In those parts of the mountains where the phenomena are most regular and most clearly displayed, we can distinguish by their bearing three sets of dykes: (i.) The radial; (ii.) the conjugate; and (iii.) the north-north-west set. The first two must be considered peculiar to the mountain district, while the third set is part of a much larger system, affecting an area which extends far beyond the limits of the Isle of Skye. It does not seem to be possible to distinguish the dykes of the several sets on petrographical grounds. One peculiar type, however, may be mentioned, consisting of an exceedingly hard and tough rock

with an orange-yellow or rusty surface. Such dykes are frequent on some of the western mountains, especially in the neighbourhood of the orange-crustcd picrite already referred to, with which they are sometimes in visible continuity. They have the same profusion of xenoliths remarked in that rock. Isle of Skye.
(Mr. A.
Harker.)

The *basic sills* intruded among the lavas make up collectively a considerable proportion of the total thickness. They vary somewhat in petrographical characters. The thicker ones are usually of a medium-grained diabase; others are of finer texture, often with something of a fissile structure. A few are amygdaloidal, but with characters quite distinct from those of the lavas, the vesicles being larger and more sporadic, and often empty. Fragments of the basalt lavas are sometimes enclosed.

The sills are always found to die out in the direction of the mountains, rarely approaching within 500 yards, and often not within 1,000 yards of the main gabbro boundary. Then follows a zone within which dykes are the only minor intrusions. Nearer to the mountains the *inclined sheets of basic rock* which form so prominent a feature of the Cuillins begin to make their appearance, traversing alike the gabbro and the enclosed patches of the volcanic group associated with it. These sheets may occur quite at the edge of the gabbro, or even in the metamorphosed basalts bordering it, but in most parts of the western Cuillins they do not become numerous at less than three-quarters of a mile or a mile from the outer boundary of the gabbro, or at altitudes of less than about 1,500 feet. They are thus quite distinct from the sills which follow the bedding-planes of the basaltic lavas. They are intimately linked with the gabbro, not only by their distribution, but by their inclination, which is always inwards towards the centre of the gabbro area. A greater variety of petrographical types among the inclined sheets also serves to separate them genetically from the sills. Which of these two groups of intrusions is the earlier is a question not easily solved. Both are evidently later than the large plutonic masses of gabbro and granite. Both are sometimes seen to cut through dykes, but this is far more frequent with the inclined sheets than with the sills. This observation, however, is not very conclusive, since we have reason to believe that the dykes in the gabbro area are in great part distinct from those of the moorland country.

Inverness-shire and Argyllshire.

In the progress of the mapping through the west of Scotland innumerable basalt-dykes are met with, having a general north-westerly trend, and presumably belonging to the third group in MR. HARKER'S classification. During the past season many examples of this series of intrusions have been noted and marked on the maps. The following illustrations of their occurrence will suffice:—

Glenelg
District.
(Mr. Clough.)

Reference has already been made to two series of dykes observed by MR. CLOUGH in the district between Glenelg and Loch Hourn. Those of the one group have been mentioned in connection with the crystalline schists. Those of the second group are no doubt of much later age, and, as they have a general north-west or north-north-west direction, and are of the same character as those of Skye, already alluded to, they may with some confidence be considered to belong to the Tertiary igneous protrusions of the west coast. They include basalts and dolerites and also some trachytic varieties. The latter are seen in several sections to be later than others of dolerite, and, as has been recorded in other districts, they show, near their sides, parallel rows of spherulites and greatly elongated amygdules.

Southern end
of Great
Glen. (Mr.
Grant
Wilson.)

In the district at the southern end of the Great Glen, surveyed last year by MR. GRANT WILSON (*ante*, p. 39) both the granulitic flagstones and the Glen Loy diorite are traversed by numerous basalt-dykes of presumably Tertiary age. These vary in breadth from one to twenty feet, and have a general easterly and westerly trend. They are more numerous on the south than on the north side of Glen Loy. It is possible that they may be connected with the volcanic "necks" on the dividing ridge to the south of the glen.*

Dalmally
District. (Mr.
Kynaston.)

A few additional examples of this late series of dykes have been noticed by MR. KYNASTON in the course of his work among the older rocks in the region already referred to (p. 42). Several dykes of dolerite, having an east and west direction, were mapped by him in the Ben Laoigh area, and between the lower portions of Glen Lochy and Glen Orchy. A dolerite near the head of Glen Shira also apparently belongs to the same series. It is a typical dolerite of medium grain, with a very fresh appearance under the microscope [8626].

Oban and
Kilmelfort.
(Mr. Symes.)

In the Oban district numerous dykes, evidently belonging to the Tertiary series, have long been known. During his field-work last season, MR. SYMES came upon a number of additional instances around Loch Melfort. The rocks along the southern shore of that inlet are cut by a series of these basalt dykes, which are numerous and well exposed. They include examples of compound dykes, like that of which an account has already been published (*Summary of Progress* for 1898, p. 155). Two of these may be seen where a stream enters the sea at Kames Bay on the east shore. A couple of olivine-basalt dykes are there split up longitudinally by basalt dykes of a less basic nature, the edges of the latter being chilled against the earlier rock, and showing a margin of black basalt-glass. Another similar illustration occurs at Kilmelfort pier, on the north side of the loch. Close to Kilmelfort and east of the Manse, the basaltic dykes are especially numerous. They stand out there in great vertical walls, rising among the schists, granite, limestone, epidiorite, &c., and as a rule running in a north-west and south-east direction. At a distance of about five miles from Kilmelfort, on Carn

* As described in the *Summary of Progress* for 1898, p. 152

Duchara, the dykes tend to assume an east and west direction, and vary in composition from a fine-grained compact basalt to a highly crystalline olivine-dolerite. Although they run in numerous parallel lines, no compound examples have been noted among them. West of Loch Losgain Beg, the Tertiary dykes are seen to cut through the felsite dykes at right angles to the lines of flow.

Nowhere on the West Coast do the late basic dykes offer a better contrast to the rocks which they traverse than they do on the western shores of the Island of Jura where the dark ribs of basalt rise through white or pale-grey quartzite. During the past season Mr. WILKINSON has mapped a number of them in the portion of the island lying north of Loch Tarbert, where, however, he has found them not quite so numerous as they are further south. They are common on the northern shores of that sea-loch, and are more especially conspicuous at the western headland of Ruantallain, where at least eight dykes rise through the quartzite close to each other. At one part of the coast a dark sill has been thrust between the beds of the quartzite, which dips towards the east, and some of the dykes rise vertically through this sill.

Isle of Jura
(Mr. Wilkin
son.)

Isle of Arran.

The survey of the remarkable succession of igneous rocks in the Island of Arran has now been nearly completed by MR. GUNN. During last season he was engaged in tracing dykes of basalt, pitchstone, and felstone in the central granite area among the crags of the highest hills, a task of some difficulty, as many of the dykes occur in almost inaccessible places, and form deep clefts that are not easy to traverse. The more minutely the granite is examined about the heads of Glen Rosie and Glen Sannox the more numerous do these dykes appear to be. MR. GUNN indeed has been led to believe that they are on the whole quite as numerous in the granite as in any other rocks of the Island. Basalt is the commonest rock among them, but dykes of pitchstone and of quartz-felsite are also abundant. With the exception of those of quartz-felsite, most of the dykes are comparatively small, many being less than ten feet in width. Composite dykes are far from uncommon. They generally consist of felstone with edges of basalt. An interesting example on Cir Mhor has been described by PROFESSOR JUDD.

In the area surveyed from Shedog, including the hill called Ard Bheinn, the rocks form part of the oval complex mentioned in a previous Report as occurring south of the String road between Brodick and Shiskine.* The geology of Ard Bheinn is about the most complicated in the island, but as none of the rocks recently collected there have been sliced for microscopical

* *Ann. Rep. Geol. Survey* for 1896, p. 75. As these pages are passing through the press a great volcanic vent in that district has been discovered by Mr. Peach and Mr. Gunn. (*Ante*, p. 133.)

(Mr. W.
Gunn.)

examination only a general description of the ground can at present be given. Indeed, only an exceedingly detailed description could give any idea of the extreme complexity of the area. The acid rocks embrace granite, granophyre, quartz-diorite, coarse quartz-porphry, and fine-grained quartz-felsite. There are also basic rocks of several kinds that appear generally to be of older date than the acid rocks, besides later dykes. The number of separate intrusions of these rocks is very great. The rock into which they are intruded is the Lower Old Red Sandstone, which is generally here a conglomerate, but so highly altered as to have quite lost its ordinary character. Some of the basic rocks are highly magnetic, and at one place 550 yards east-south-east from Dereneneach the rock is a natural magnet, and possesses polarity. The characters, relations and age of these rocks remain to be determined.

PLEISTOCENE, INCLUDING GLACIAL.

Though no new facts of importance in the investigation of the Pleistocene deposits of the British Isles have been elicited during the past year by the field-work of the Geological Survey, much additional information has been collected regarding the distribution and local character of these deposits. In the following brief summary of the observations a geographical order will be followed, beginning with the English Midland and Southern Counties, then passing to South Wales, taking the districts of Scotland in order from north to south, and concluding with those of the south-east of Ireland.

Midlands.

Leicester and
Rutland.
(Mr. Fox
Strangways.)

In the portions of the counties of Leicester and Rutland examined by MR. FOX STRANGWAYS he has found the distribution of the boulder-clay and gravel to be somewhat irregular. As a rule, these materials cap most of the higher ground, while the valleys are free from them. There are, however, exceptions to this rule, as over the high ground about Burrow and Somerby these deposits have been almost entirely removed, and also along the ridge from Whatborough Hill to the south-east. A large area free of Drift extends from between Tugby and Goadby eastwards to the north of Hallaton and Horninghold. Besides these tracts nearly all the valleys are devoid of drift in their lower part, except in two instances near Skeffington Vale and near Illston Grange, where boulder-clay is seen in the stream sections. The boulder-clay attains its greatest thickness along the southern edge of the map, a well west of Hallaton being said to be 150 feet deep, and apparently entirely in this deposit. Such a depth, however, must be exceptional, as elsewhere the drift does not appear to be of great thickness. The chief deposits of gravel are at Tilton, Skeffington, Rolleston, Tugby, and Belton. The

revised edition of the map will show considerable changes in the mapping of the superficial deposits.

Reference was made in last *Summary of Progress* to some interesting particulars regarding the distribution of the boulder clays and boulders in the North Staffordshire region, which were gathered during the revision by MR. LAMPLUGH. In the work of last season, MR. BARROW obtained some fresh corroborative evidence of the same facts in the Leek and Cheadle district. He appears to have traced a portion of one of the marginal lobes of the ice-sheet that moved out of the Irish Sea, and carried with it the boulders from the Lake District. It will be remembered that MR. LAMPLUGH noticed that the ground between Cheadle and Uttoxeter was marked by an absence of these boulders, and he conjectured that the lower layers of the north-western ice, in which these stones were chiefly lodged, were arrested by the steep Bunter escarpment south of Cheadle. MR. BARROW, in confirming this surmise, has found that the arrest took place rather further to the north, but was effected by another prominent topographical feature of a similar kind. He has traced the north-western drift, with its abundant blocks from the Lake country, in great force over the ground to the north of Leek. This drift contains a great number of chips of flint, a characteristic feature of the boulder-clays of the Irish Sea basin. The blocks of igneous rocks from the Lake District cease to be visible a little south of Wetley Rocks. Roughly speaking, a line may be drawn in an easterly direction from this point, south of which these boulders have not been met with. Starting again from the same locality the further limit is no longer an east-west line, but a north-south one. In other words the limit of the drift is marked by a line that forms a right angle at a point a little south of Wetley. The position of this line is shown on a geological map to correspond through a considerable part of its course with the foot of the escarpment of the third grit—the rock that makes the most pronounced topographical feature in the whole area, and would obviously present the most persistent obstacle to the advance of the ice. The area beyond this line often contains no drift except a few Bunter pebbles, which are as ubiquitous in this part of England as chalk-flints are in other areas. On the east side of the Churnet there is no appreciable cover of drift. But the materials used in the construction of walls bear record of the transport of local boulders by ice, for these consist largely of the First and Third Grits, the outcrop of which is often not more than a mile distant. The bottoms of the small but deep valleys in the shales are often full of boulders of these local rocks. It was obviously economical to clear the fields of these blocks and use them for building walls, but it did not pay to undertake the great labour of hauling them out of the beds of the streams, and there they remain to attest the great number of boulders that have been transported by ice, though no drift now remains that can be represented on a map.

In the western part of North Staffordshire, which has been revised by MR. C. B. WEDD, little can be added to what was said

North
Staffordshire.
(Mr. Barrow.)

(Mr. C. B.
Wedd.)

(Mr. C. B.
Wedd.)

of the Drift in last year's *Summary of Progress*. In the Audley and Talke district the drift terminates against the anticlinal ridges of the Coal-measure sandstones on the east, but where these ridges are broken by transverse valleys the drift passes southwards and south-eastwards up these valleys. On a belt of ground about a mile and a half broad, immediately west of these ridges, the drift is thin, except in valleys, while ridges of Triassic and Upper Coal-measure strata often rise from the midst of it. Beyond this it thickens to the west. It consists here as elsewhere of clays, sands, and gravels. The occurrence of shell-fragments in these deposits, which was referred to in last *Summary of Progress*, has been further proved by MR. WEDD during the past year. He has now found these fragments at 46 localities in the district, but few, if any, forms have been noted in addition to those given in the list published in that *Summary*. In the neighbourhood of Caverswall and Blythe Bridge little drift occurs, except in and north of the Blythe Valley, but no shell-fragments have been found in it. Many large boulders of some five or six types occur on the high Bunter ground of this part of the district. In the more westerly ground several peat-mosses occur, resting in hollows in sand, or closely associated with it.

(Mr. W.
Gibson.)

In the centre of the Pottery Coal-field, MR. GIBSON has observed that the drift deposits are thin and sparsely distributed, though they are developed in considerable quantities in the Trent Valley round Bucknall. At Kids Grove another example of the edge of an ice lobe may be seen. The highly-inclined Coal-measures there rise abruptly above the Plain of Cheshire, and the drift deposits end off abruptly against the Carboniferous strata at an elevation of 500 feet, but drift sand and gravel occur at Trubshaw at an elevation of 700 feet.

Cheshire.
(Mr. T. I.
Pocock.)

In the district of Crewe and further to the north-east in the country around Macclesfield the Drifts have been mapped by MR. T. I. POCOCK. It is well known that on the west side of the Pennine chain these deposits reach a height of 1,300 feet above the sea. Some patches of this high-level drift have been recently examined by MR. POCOCK. They consist of false-bedded sands with courses of pebbles (derived for the most part from the Lake District and Scotland), and rest here and there on boulder-clay. The amount of boulder-clay at the high levels is, however, small. The best known of these patches (that which yielded the marine fossils discovered by PROFESSOR PRESTWICH), runs for nearly a mile at the foot of an escarpment of grit north-east of Walker Barn. Others have been seen by the brook side east of Forest Chapel. The tops of the ridges above are plentifully strewn with boulders from the Lake country and Scotland, which afford conclusive evidence that some portion of the ice-sheet covered the spur of the Pennine Hills east of Macclesfield. The occurrence of drift and boulders by the brook which flows through Wild Boar Clough shows that the ice passed between Shutlingslow and the main ridge of the Pennine Hills. The peak of the Shutlingslow (two miles south from Forest Chapel), may have been a "nunatak" in the stream

of ice. No erratics appear to have been recorded from the top of the main ridge, and probably the long escarpment formed by the third grit, which rises to a height of more than 1,800 feet at Shining Tor, barred the progress of the ice to the east. Cheshire.
(Mr. T. I. Pocock.)

Besides the isolated patches of drift at high levels a series of mounds of sand and gravel was met with in the Langley Valley, two miles south-east of Macclesfield, about 700 feet above the sea. They are composed of the same materials as the drift at higher levels and take the form of conical heaps or undulating ridges, more or less parallel with the trend of the valleys. Their form, and mode of occurrence, at the point where the valley opens out on to the lowlands of Cheshire, recall the kames of the South of Scotland. They appear to have suffered little denudation since they were deposited. They may have been formed by torrential waters at a time when the ice-sheet barred the mouth of the valley, and the pressure from the north was not strong enough to force it over the tops of the hills.

In the Hilderstone district drift occurs sparingly on the tops of the hills, which rise to 700 feet above the sea, and also in the bottoms of the valleys, but the slopes are generally free from it. Ice-worn surfaces were met with near Fulford which indicate that the ice passed down Fulford Dale in an east-south-east direction. The drift, which is of the type described by MR. LAMPLUGH,* is mainly composed of *débris* of Bunter pebble-beds with a mixture of red clay where it rests on the Keuper Marl. The occasional presence of striated pebbles from the Lake country clearly indicates its glacial origin.

In the Crewe district the drift is of the type common all over the Cheshire Plain. It is not more than 40 feet thick near Crewe, but is much thicker elsewhere. The false-bedded sands, which occupy a larger area than the clay in this district, can be traced continuously from Crewe Park through Weston and Wybunbury to Willaston. Here and there in brook-sections they may be seen to occupy a position between an upper and a lower boulder-clay. But as a rule this is not the case.

The three-fold succession described by MR. DE RANCE in his Memoir on the Drift of South-west Lancashire, where the upper clay rests on an irregular surface of middle sands, or of a lower clay which closely resembles the upper, may hold good in the Crewe district. But the difficulty of distinguishing the two clays makes it impracticable to establish such a relation, or at least to use it for purposes of mapping.

Of the erratic boulders found in the course of MR. POCOCK'S work last season the great majority belong to the same rocks as those described by MR. HARKER in the *Summary of Progress* for 1898. Some of the others were submitted to MR. PEACH, and were considered by him to belong to the Silurian *grauwackes* and granites of the south of Scotland. Another may have been derived from the *Calceiferous Sandstones* of the Border-country.

* *Summary of Progress* for 1898, p. 160.

Hampshire Basin.

(Mr. Clement
Reid.)

The Drifts mapped by MR. CLEMENT REID in the Avon Valley consist in the main of tier above tier of gravel terraces, the highest of which rises fully 300 feet above the Avon, and not improbably dates back to Newer Pliocene times. These higher gravels are mainly preserved on the east side of the river, and, as is the case in all the Hampshire Basin, the gravels nearly cease where the Chalk crops out. The reason why the ancient valley gravels are so commonly confined to the Eocene area, and scarcely cross over to the Chalk, is by no means obvious, though it is probably due to the peculiar type of denudation which took place under an Arctic climate, when the undulating surface of the Down was frozen and no longer pervious. The 100 foot terrace (about 100 feet above the Avon) is the lowest of the gravel terraces here referred to. It is a continuation of the Bournemouth sheet, and contains, like that sheet, Palæolithic implements.

The Valley Gravels can sometimes be divided into two or three terraces, as MR. WESTLAKE has already shown; more commonly they form a continuous slope, rising 40 or 50 feet above the river, where the terrace abuts against the steep bluff which everywhere borders the Avon flat. These gravels yield remains of Mammoth, and also rare Palæolithic implements; but, like the older series, they are usually decalcified, and show no trace of fossils.

In the adjoining Dorset area, mapped by MR. DIXON, a few outliers of the high terraces are to be found; but the highest is only 240 feet above the river, and is probably somewhat newer than the sheet over which the Downton and Southampton road passes.

Sussex.

(Mr.
Lamplugh.)

In the area of Sussex, which has already been referred to (p. 135) as having been mapped last season by MR. LAMPLUGH, the oldest superficial deposit is a coarse, flinty rubble, which forms an irregular capping on plateaux of limited extent on the Folkestone and occasionally on the Sandgate Beds south of the Rother valley. These little plateaux, much dissected by erosion, slope gently northward (*i.e.*, away from the South Downs), but end off boldly above the depression occupied by the Gault in steep bluffs simulating an escarpment, sometimes 50 to 80 feet high. The rubble on these plateaux has an extreme depth of nine or ten feet in "piped" hollows, but is oftener a mere ragged film, through which the underlying formation continually breaks. It is best developed on the commons of Heyshot, Ambersham, Graffham and Coates, and is much dug for road-mending. This material was a subject of discussion nearly fifty years ago

by SIR R. I. MURCHISON,* and more recently by MR. J. V. EILSDEN.† Its accumulation probably dates back to the Glacial Period, and must have taken place under peculiar physical conditions. That the plateaux have suffered very little surface-erosion since pre-historic times is shown by the position of the tumuli on some of the spurs overlooking the Gault depression.

South Wales.

The following summary of work of MESSRS. STRAHAN, TIDDE-
MAN and CANTRILL last season among the Pleistocene phenomena
of South Wales has been drawn up by MR. STRAHAN. In
previous Reports reference has been made to the Brecknock
escarpment of Old Red Sandstone as having been no less
important as an ice-parting in Glacial times than it is as a water-
parting at the present day, but in the *Summary of Progress* for
1898 several facts were cited which suggest that the western end
of that escarpment was crossed by the ice by way of the Crai
and Tawyneu valleys. Further evidence of such crossing has
been obtained by MR. CANTRILL in Cwm Garw. He finds that
in that valley the ice, as shown by striæ on rock in place, moved
in a general southerly direction, and that the valley contains
many boulders of Old Red Sandstone, although the outcrop of
that rock occurs beyond the head of the valley and on the other
(northern) side of the water-parting. He infers that the ice
overflowed the range southward by the pass of Pen rhiw wen, at
a height of 1,618 feet, and that this overflow must have been due
to the Vale of Towy having been filled with ice to at least that
height.

(Mr. Strahan
Mr. Tidde-
man, and Mr.
Cantrill.)

MR. CANTRILL notes also the occurrence of many striæ, *roches moutonnées*, and bevelled crags on the Millstone Grit west of the Gwys. Tyle Garw shows numerous glaciæted surfaces, the striæ indicating an ice-flow down Cwm Twrch in a south-south-west direction. The high Millstone Grit plateau lying between the rivers Tarch and Llynfell is glaciæted right across its summit (1,656 ft.) in a direction towards south 15° west, by ice which must have moved up from somewhat lower ground to the north.

Along the north-west flank of the ridge known as Tair earn isaf, striæ have been recognised up to a height of 1,371 feet, with a direction ranging from south 60° west to south 15° west, indicating a general south-west flow parallel to the Llwehwr Valley.

The undulating plain underlain by the lower part of the Coal-measures is thickly overspread by a tough blue till full of large and small glaciæted boulders, chiefly of Millstone Grit, but with abundant pieces of Old Red Sandstone and Carboniferous Limestone also. Through this deposit the rivers Giedd, Gwys, Twrch, and Llynfell have cut steep-sided ravines down into the under-

* *Quart. Journ. Geol. Soc.*, vol. vii., pp. 351-361.

† *Quart. Journ. Geol. Soc.*, vol. xliii., pp. 637-656.

(Mr. Strahan,
Mr. Tidde-
man, and Mr.
Cantrill.)

lying rocks. These post-glacial ravines run about south 10° - 15° west, and cut obliquely across the gentle ridges into which the Drift was piled, which run west 10° to 30° south. The direction assumed by these ridges prepares us for the fact that the main mass of the Brecknock Drift travelled along the north crop westwards, though some also certainly found a way down the Upper Clydach and Egel valleys past Rhyd-y-fro.

The Tawe Valley, like that of the Neath, formed one of the main outlets for the Brecknock Drift. Boulders of Old Red Sandstone and Limestone abound along its whole course, and are even piled up high on the hillsides around Swansea Bay. Striæ have been noticed in a paving quarry on Allt-wen, 400 feet above the bottom of the valley at Pontardawe, and at about the same elevation on the top of a sandstone-crag west of Ynys-meudwy. On Kilvey Hill, east of Swansea, there are many glaciated rock-surfaces, but none on which striæ were sufficiently preserved to be recorded. The Brecknock Drift runs up to a height of 550 feet at least on this hill; it is doubtful, in fact, whether there is any ground around Swansea which was not overflowed by the ice. The Drift in the upper part of the Tawe Valley may be described as a till, but in accordance with the usual rule it gets more gravelly farther from its source. The boulders, which are chiefly angular near the source in Brecknock, get steadily rounder, until at Swansea they are all true pebbles. The whole deposit also changes its character and assumes a rough stratification, in which sands alternate with pebble-gravels, while at the same time it has been heaped up into the ridge-and-hollow form so characteristic of glacial gravels. This form is admirably illustrated from Glais downwards. At that place a great dam of coarse gravel, reaching to a height of about 100 feet above the alluvium, extends far out in the valley, deflecting the river and leaving a narrow outlet for it at Clydach. Llansamlet also is situated among mounds of sand and gravel, the hollows between which have been filled up by flood-deposits of the Tawe and partly by peat.

The Drift-dam at Glais reproduces the phenomena already referred to* with respect to the Vale of Neath. The sands and gravels seem to have been the work of effluents from the ice-foot, and their development, especially in the form of a conspicuous ridge such as that at Glais, points to the ice-foot having lingered at that spot. It may be remarked of that ridge also that it presents a fairly gentle slope towards the north, but an extremely steep face to the south. It therefore has exactly the form which has been noticed in ice-foot accumulations at the present day, the gentle slope being produced by the advance and retreat of the ice over the rubbish, and the steep face by the extrusion of the material from the ice-foot.

The examination of the superficial deposits of Gower by MR. TIDDEMAN has enabled him to prove a fact of much importance with respect to the relative age of the Raised Beach and the

* *Summary of Progress for 1898*, p. 165.

Glacial Deposits of the neighbourhood. This relation had been (Mr. Strahan, discussed, especially by Falconer* and Prestwich, but in consequence of the researches having been carried on chiefly in connection with the exploration of caves, and in a part of the coast where the evidence was obscure, Prestwich found himself unable to form a decided opinion. From an examination of the coast between Bacon Hole and Mumbles Head, MR. TIDDEMAN has satisfied himself:—

(Mr. Tidde-
man, and Mr.
Cantrill.)

1. That the Raised Beach is ~~pre-~~ or inter-glacial.
2. That the bone-beds which rest upon it in the caves are continuous with a layer of angular débris ("head") which lies upon it.
3. That the Glacial Beds lie upon this.
4. That these in turn are often covered with a deposit of angular débris of post-glacial age.

The lowest bed seen so far consists of a mass of pebbles, more or less crowded with shells of such species as are living on the coast at the present day. The pebbles consist of limestone, with an occasional specimen of Old Red or Carboniferous sandstone. There are also a few fragments of yellow flint or chert of doubtful origin. The conglomerate is firmly cemented. This deposit is overlain by a foxy-red sand, which, though impersistent, often runs for some distance. It is evidently a sand blown up from the foreshore and sometimes contains land-shells (*Helix*), which abound on the modern blown sands. The presence of this bed implies a sandy foreshore in some parts where no sands are found at low water now.

The next deposit rests on the sand, or, in its absence, on the beach or on the solid rock. It is to all appearance made up entirely of broken and angular limestone from the crags above. Its thickness varies greatly according to local circumstances. The glacial drift which rests upon the last-described band offers a remarkable contrast. It contains but little limestone, while Carboniferous sandstones and pebbles of Old Red Sandstone abound. This drift, which sometimes reaches a thickness of 40 feet, is in some places made up of rounded boulders and gravel, while in others semi-angular débris is more common.

Ross-shire and Inverness-shire.

During the past working season fresh proofs have been collected by MR. PEACH in the eastern parts of Ross-shire of the magnitude of the later glaciation of that region, to which allusion has already been made.† Both from the direction of the striæ on the bare rock-surfaces, and from the distribution of the boulders, especially those of the conspicuous Inchbae

Dingwall
District. (Mr.
B. N. Peach.)

* *Pal. Memoirs*, vol. ii., pp. 357, 358, 535.

† *Summary of Progress* for 1898, pp. 174, 175.

augen-gneiss, it is manifest that the ice was developed on such an enormous scale that the eastern margin of the great confluent glacier of the Blackwater and Conan rose high up the flanks of Ben Wyvis, and that on its emergence upon the low ground to the south of that mountain the ice must have fanned out towards the east. The southern slopes of the hill are terraced with successive lateral moraines strewn with boulders of the Inchbae rock, which mark successive stages in the decrease of the glacier.

Beaully Dis-
trict. (Mr. L.
Hinxman.)

The glaciation of the region lying to the south of MR. PEACH'S ground has been studied by MR. HINXMAN, who has observed that in the district between Strath Conan and Strath Glass most of the glacial phenomena are again found to belong to the later phases of the Glacial Period, few traces having been detected of the earliest glaciation since these have been in large measure effaced by the gigantic glaciers of later time.

On the summit ridge of Bheinn a' Bh'ach Ard, in the Struy forest, large erratic blocks of muscovite-biotite-gneiss and granite are forced up to heights of 2,800 feet. These must have been deposited by an ice-sheet coming from the west and over-riding the general surface of the country. Hard grey till, filled with angular blocks, underlies the later moraine deposits in the upper part of Glen Orrin near Aradie; and isolated patches of a similar early boulder-clay are found on the slopes of the higher hills north of Struy. On the ridge between Scatwell and Glen Orrin a few striæ pointing south-south-east have been observed. These indicate an ice-movement across the main valley system, and may possibly be due to the early ice-sheet. They may, on the other hand, have been produced by a branch of the Strath Bran glacier coming from the north through the narrow glen at the foot of Loch Luichart.

The lower hilly ground to the east of Erchless is for the most part bare of drift, and the rocks are well glaciated. The numerous striæ point north-east to east-north-east, a direction slightly oblique to the trend of the valley. The glaciation of this area and of that adjoining it on the north may be assigned to an early period of the valley glaciation—the period of the confluence of the Conan, Orrin, and Strathfarrar glaciers on the comparatively low ground to the east of Erchless and Corriechallie.

It is the last phase of the valley ice—that of small individual glaciers shrinking up the glens—that has produced the most striking glacial phenomena in the district. In the lower parts of Glen Orrin and Glen Goibhre the terraced lateral moraines, produced by the shrinking ice, are well displayed; and a particularly fine example encircles Cnoc Judais, the steep hill of conglomerate that rises west of the farm of Auchmore. East of this point they merge into the lateral moraines formed along the southern edge of the Strathconan glacier on the hill slopes above Balavulich and Ord Mains, and descending to the lower ground about Ord, pass into a series of flat-topped mounds and ridges of fluvio-glacial gravel, the latter finally spreading out into a fan and merging into the deposits of the 100 feet beach between High-

field and Muir of Ord. Higher up Strathconan, the terminal moraines of the retreating glacier cover the bottom of the valley about Scatwell, and immediately west of Muirton Mains can be seen surrounded by, and no doubt resting upon, the 100-foot beach.

Beaully District. (Mr. L. Hinxman.)

Large boulders of the Inchbae augen-gneiss, together with blocks of gneiss, schist, and amphibolite, are found in great numbers about Arcan on the smooth drift-covered ridge between the Conan and the Orrin. The latter river seems to form the southern boundary of the dispersion of these augen-gneiss erratics. Eastwards, blocks of the same rock are numerous on the southern slope of the Black Isle, as mentioned in last *Summary of Progress* (p. 174). The stone circle at Carnurnan is formed of blocks of this gneiss, together with a few of mica-trap which enclose pebbles out of the Old Red Conglomerate. MR. PEACH has described a rock of this nature as occurring on Creag a Chaoruinn, south of Loch Garve, 12 miles to the west-north-west, from which place these erratics have not improbably been derived.

Among the glacial deposits of Scotland must be reckoned the older strand-lines or raised beaches which form so marked a feature on the eastern and western coastlines of the country. Some of these terraces are admirably developed among the northern firths from Inverness to the borders of Sutherland. One of the most marked of them, known as the 100-foot terrace, has been traced by MR. HINXMAN up the valley of the Conan to the extreme limit of the 100 feet contour opposite Torrachilty. Between Marybank and Clachuile Inn it is much denuded and sometimes obscured by river gravel. Immediately west of Muirton Mains it forms a considerable feature, and nearly surrounds a promontory of morainic material which, as mentioned above, appears to have been laid down upon the pre-existing beach. At this point the beach is composed of finely-laminated blue and grey estuarine clay, in which marine shells, not at the time identified, were obtained during draining operations.

The hollows and hill-slopes in Glen Goibhre and the Erchless Forest, and the plateau between Scatwell and Glen Orrin, are occupied by peat mosses of considerable extent and thickness. Most of the more accessible of these are dug for fuel.

In continuation of his previous work in the district of Fannich Forest MR. HORNE mapped some well-marked groups of valley moraines in the Abhuinn Nid and Cabuie Valley. When later in the year he transferred his station to Strath Nairn he found good evidence of the north-easterly movement of the great mass of ice which emerged from the Great Glen and spread out over the low grounds of the Moray Firth. This evidence consists of rock-striae, the transport of materials in the boulder-clay and the dispersion of erratic blocks. The phenomena of the later glaciation were observed to be well represented by a fine development of valley moraines.

Fannich Forest and Strath Nairn. (Mr. Horne.)

In the west of Inverness-shire MR. CLOUGH has gathered

Glenelg District. (Mr. Clough.)

further information regarding the glaciation of the mountainous region to the south of Glenelg. In the area west of Beinn a'Chapuill and Ben Sgriol he has not observed much drift, but many of the glens to the east show extensive tracts of morainic heaps. Near the tops of Ben Sgriol (3,196 feet) and the Saddle (3,317 feet), and some other hills, he has observed flats and slopes which are chiefly covered with angular or subangular slabs of Moine-rocks like those which occur *in situ* near at hand, but without any admixture of stones, which must necessarily have been transported from a great distance. On the south slopes of the Saddle ice-striae, pointing west and south-west, were noticed at a height of about 2,500 feet. The tops of Beinn a' Chapuill (2,421 feet) and of Sgurr na Laire Brice (2,326 feet) seem to have been covered by the ice, for ice-striae may be seen close to the top of each; the direction of the striae on Beinn a' Chapuill is south-east, and on Sgurr na Laire Brice north-east or east-north-east.

The terrace of the 100-feet raised beach is well seen on the south side of Gleann Beag of Glenelg. It runs for nearly a mile and a half above the mouth of the glen, and appears also on the coast near An Gurraban and Rudha Mòr. The hamlets of Arnisdale and Corran are built on a raised beach which, along the sea margin, reaches in places to a height of about forty feet. But the continuation of this beach inland in a terrace-form at the sides of Arnisdale river reaches a considerably greater height. On the north side of the river, about half a mile east-south-east of Arnisdale House, within the area of the high terrace, various banks and mounds are to be seen which resemble moraines. They seem all composed of well-rounded gravel.

On the south side of the same river, opposite to these mounds a terrace-shaped deposit of fine, stoneless, laminated, sandy clay, and sandy gravel lies at a height of perhaps 200 feet above the sea. At least one other terrace-shaped deposit occurs at a greater height, but its materials are not seen in section. Possibly these sediments were laid down at the side of an ice-tongue, which still filled most of the valley.

On the west side of Allt Coire Utha a large landslip has taken place. It appears to have at first dammed the burn back and given rise to a small lake. But the site of the lake is now filled up with gravel brought down by the stream. Other landslips have occurred on the south side of Gleann Beag (near Balyraid), and on Druim Fada.

Argyllshire.

Glen Spean and the Great Glen. (Mr. Grant Wilson.)

The glacial phenomena of Glen Spean and the Great Glen have long been classic in geology. They have never been actually mapped, however, in a detailed survey on such a scale as that now employed in the field-work of the Geological Survey. MR. GRANT WILSON, to whom this region has been assigned, has now made some progress with the mapping of the

superficial deposits, and has furnished the following notes regarding the results obtained last season. One interesting feature of his mapping is the discovery of evidence for the former existence of a succession of lakes at various levels below the famous "Parallel Roads," during the time of the shrinkage of the ice-barrier that gave rise to them.

Glen Spean
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Wilson.)

No characteristic of the region stands out more strikingly than the proofs of the enormous magnitude of the ice-streams during the later glaciation, especially on the west side of the Great Glen. At that time the ice while at its greatest extension, must have formed a large confluent glacier or ice-sheet over the ground between Loch Eil and Loch Arkaig. It moved eastward descending into the wide glen, and leaving traces of the successive stages of its decrease in the form of large lateral moraines which still terrace the slopes of the hills, and the sides of the valleys from top to bottom. So vast was this body of ice that it actually crossed to the south-east side of the Great Glen.* Round the township of Brackletter south of the mouth of the river Spean, the direction of the rock-striæ is from east 15° north to east 25° north; also on the east side of Loch Lochy to the south of Glenfintaig House, the striæ vary in direction from south 5° east to south 25° east. Two miles inland on the south-west shoulder of Sròn nam Bà, a fine series of striæ has been recorded. These generally indicate a movement in the direction of east 15° to 35° S, and that the ice from Glen Arkaig had passed over the hollow now occupied by Loch Lochy and the Dochanassie district on its eastern side. From the direction of these different sets of striæ it appears that part of the ice from Loch Eil and the whole of that from Glen Arkaig converged towards the Spean valley.

That the movement of the ice of the later glaciation was from west to east over this district of Lochaber is further indicated by an analysis of the contents of the moraines. On the Fort Augustus Railway, below the Free Church of Kilmonivaig, a cutting has recently been made through sand and gravel resting on packed morainic detritus. As the material was removed the boulders of the moraine were placed on one side. A careful examination showed that fully 95 per cent. of them consisted of various rocks that occur *in situ* towards the west. A similar result has been obtained from an examination of the moraine sections exposed on the roadside that leads from Torlundy to Linachan.

Farther proof of the same general trend of the ice has also been collected in a study of the morainic detritus which fills the bottom of the valley of the Allt a' Mhuilinn, on the north-west slope of Ben Nevis. From the foot of the hill, for some miles to the east of the watershed, the underlying rock is granite, while the moraines are almost entirely made up of rocks from the Loch Eil basin and the country to the west. The ice has here not only carried the morainic detritus across the wide valley from Corpach to Inverlochy, but also up the slopes of

* See Mr. T. F. Jamieson's paper, *Quart. Journ. Geol. Soc.*, vol. xix., p. 235.

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Wilson.)

Ben Nevis to a height of at least 2,000 feet above sea-level. It is evident that during this period of glaciation the local glaciers that emanated from the Ben Nevis range could only have been insignificant in size. Indeed, at no time could these glaciers have been large, seeing that the *nevé*-field of this range is so limited in extent.

During the past season numerous observations have been made by MR. GRANT WILSON in illustration of the later stages of the ice as it melted back towards the west, and the physical features that it gave rise to in Glen Spean. To the north of Spean Bridge the 855-foot Parallel Road is not correctly laid down on the one-inch Ordnance map. It should end about half a mile further to the east than is there represented. To the south of this point a well-marked terrace at the level of 420 feet extends from behind the house of Tirandrish to the foot of Glen Collarig in Glen Roy. This terrace is composed either of fine sand or of glacial silt, and where the Allt-na-Grudiareach has cut a deep trench across it, the following section is exposed :—

	Ft.	In.
Sandy soil - - - - -	21	5
Light brown glacial silt, laminated, with a few stones -	2	0
Fine clean gravel, stones up to the size of peas - -	0	5
Very fine clean sharp sand - - - - -	1	6
Gravel, sharp and clean - - - - -	0	6
Sand with gravel bands - - - - -	0	9
Light brown glacial silt, laminated with stones - -	1	0
Gravel, sharp, bottom not seen - - - - -	3	0
	<u>10</u>	<u>8</u>

A similar terrace at the same level has been traced on the south side of the River Spean from a point opposite Tirandrish round by Killiehonnet, thence up the Cour Valley and Allt-an-Loin till it merges into the flat which marks the site of Loch Lianachan. Fringing the south-side of the Allt-an-Loin, this terrace forms an extensive flat to the south of Dalnabie and continues up the valley as far as a point opposite the Roman Catholic Chapel of Glen Spean.

At many points around Dalnabie numerous landslips and cuttings show the terrace to be composed of fine glacial silt or sand, and in some cases these rest upon morainic detritus. Between the Roman Catholic Chapel and the foot of Glen Collarig, a well-marked flat-topped, broad terrace lies around the west foot of Meall Dhoire with its shore margin reaching to a height of about 420 feet. At the roadside below Auchaderry* its slope towards the deep water of the lake is seen to consist of 20 feet of fine white glacial sand in thin horizontal layers.

These three portions of a terrace appear to mark the site of another glacial lake in Glen Spean, which stood at a height of 420 above the present sea-level. When the ice which formed the barrier of the 855-foot lake had sufficiently diminished, its waters would find their way out in the direction of the valley of

* *Op. cit.*, p. 251.

the Lundy, at the same time depositing the large accumulation of false-bedded sands and gravels which are found at the head of the River Lundy between Torr Sonnachain and Sgor a' Pheanais. The 855-foot lake of Glen Spean and Glen Roy would thus be reduced to the 420-foot lake of Glen Spean, with its ice barrier stretching across the Spean Valley at Tirandrish. The surplus water of this lower lake would escape over the Col 420 feet at the south-west corner of Lake Lianachan. The barrier at Tirandrish must have been entirely composed of ice, for no terminal moraine extends across the valley at this point.

The next stage in the retrocession of the ice sheet from the Spean Valley is marked by the lowering of the 420-foot lake and its replacement by that of 300 feet. This later sheet of water was about $5\frac{1}{2}$ miles long with an average breadth of half a mile. It stretched from Brackletter to the foot of Glen Roy. On the north side of the railway viaduct the line passes into a cutting* 250 yards long, which gives the following section of the materials deposited at the bottom of this lake.

	Ft.	In.
Fine gravel	3	0
Fine laminated brown silt with a few stones	20	0
Fine laminated blue silt (contorted by shore ice)	3	5
bottom not seen	26	5

Both the brown and blue silt are arranged in fine horizontal laminae, and through both are scattered a few glacial pebbles. At the foot of the sloping bank the silt has been contorted and folded, possibly by the effects of the stranding of ice during the period of deposition. Around the church and the house of Blairour, numerous pit-sections show that the waters of the lake here deposited bands of fine glacial silt and sand with scattered glacial pebbles. From the road-section below the church the thickness of the lacustrine deposit is seen to be about 50 feet.

On the south side of the river around Dalnabie, the finer deposits left by this lake have been denuded by the River Spean, and are replaced by the coarser and more recent alluvial gravels, but on the north side between Inveroy and Roy Bridge a broad, well-marked terrace with its shore-edge reaching to the 300-foot contour-line has been preserved.

When the lake at a level of 420 feet was superseded by this lower lake, the River Roy at the foot of its glen cut away a portion of the deposit laid down on the floor of the higher sheet of water, and left a long sloping terrace of silt covered by a thin deposit of gravel, now found midway between the two benches which mark the limit of the respective lakes.

A good part of the silt and sand deposited by the muddy waters of this lower lake has since been wholly or partially removed by the stream which has laid down in its place at a

* *Summary of Progress for 1898*, p. 171.

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lower level terraces of coarse alluvial gravel. This change is well seen in the railway cutting on the south side of the Spean, which passes through one of the upper river-terraces, showing current-bedded stream-gravel resting unconformably on a denuded surface of horizontally-bedded glacial silt. The barrier which impounded the waters of this lake extended from Brackletter to Torr-an-Eas, and was partly composed of ice and partly of moraine-detritus. At the cross-roads below Torr-an-Eas, the moraine has a height of 361 feet. On the opposite side it is represented by the flat-topped hill of Brackletter (371 feet), and in all probability once stretched right across what is now the deep river-gorge. This large accumulation of morainic detritus has an average breadth of about 500 yards.

In a railway cutting below the Free Church of Kilmonevaig, and on the west side of the barrier, it is seen that the portion which has been removed by the river consists of hard, packed morainic detritus, containing large boulders. The moraine in this cutting reaches a height of 230 feet above sea-level, and on its denuded top there rests a capping of false-bedded sand and gravel, about 15 to 20 feet thick. The dam would thus appear to have been lowered to the top of the moraine, while the out-flowing water deposited the sand and gravel. The surplus water of the lake found its way into the Allt Achadh na Dalach, to the south-west of Spean Bridge. The present level of the col is a little over 270 feet, but when the lake overflowed in this direction, there may have been a considerable body of ice resting on the col, for the bottom of the gap is covered with small moraines, and below Auchnabobanne the valley is crossed by three large ridges, composed of morainic detritus. These mounds more nearly resemble kames than ordinary terminal moraines. They rise above the usual moraine hillocks, cross the valley with a serpentine course, and creep up the rising ground on both sides to at least 100 feet higher than in the centre of the valley. They are possibly due to the water, which must have circulated upon, within, or beneath the melting ice-sheet.

After the ice finally retreated from the foot of the Spean gorge, a large glacier would seem to have still issued from Glen Arkaig, and to have pushed its terminal face from Clunes to the braes on the west side of Brackletter. This ice-barrier would raise the surface of Loch Lochy. That the lake did really stand at a higher level is proved by the well-defined terraces, 35 feet above the present level of the water between Mucomir and Glenfintaig House, and around Blar-an-lochain.

Dalmally
District. (Mr.
Kynaston.)

From Dalmally Mr. KYNASTON was able to map the drifts and other glacial phenomena, both southwards across the watershed towards Loch Fyne, and northward in the glens that drain into Loch Awe. From that part of Glen Shira nearest to the Cladich Burn he traced a continuous series of morainic mounds across the intervening divide and down to Loch Awe-side. The ice from the Ben Bhuidhe ground, no doubt, in part at one time travelled in this direction, and spread completely over the hills

between Glen Shira and Glen Aray. The presence of a large boulder of monzonite, of the Ben Bhuidhe type, at the head of Glen Aray is of interest in this connection. Dalmally District. (Mr. Kynaston.)

In Glen Lochy the morainic drift is well marked and extensive, and good sections of the mounds of loose material may be seen in the railway cuttings.

In the Glen Orchy area the larger burns (*e.g.*, Allt Corrie Bhiacair) have often cut their channels through more than 40 feet of mixed morainic material. Continuous morainic deposits may be traced from the head of Glen Strae down into Glen Orchy to the east, into the Black Mount on the north, and over into Glen-kinglass on the north-west. In this district boulders of rocks, possessing characteristic and easily recognisable features, such as monzonite and the porphyritic augite-diorite, show that their dispersion has mainly followed the lines of the greater glens. Occasional large boulders of the Glen Orchy monzonite occur at Dalmally, while in the more immediate neighbourhood of the parent rock a line of boulders may be followed in a south-westerly direction, up a branch of the burn in which the rock occurs in place, and up the hill slopes between that branch and Glen Orchy, to a height of nearly 1,500 feet, or about 600 feet above the exposed parent rock.

In the district around Kilmelfort MR. SYMES has observed that the striation on the ice-worn rock surface has a general east and west direction, varying up to as much as W. 45° S., which is the trend of striae a mile to the south-west of the village. The ice is thus shown to have moved westwards, and to have inclined to the south of west, and even to south-west, according to the form of the ground. The most noticeable departure from this general trend was observed in the Pass of Melfort, which runs north and south, and where the striae follow the same direction. As a rule these ice-markings have usually disappeared from the exposed surfaces of the knolls and crags of andesite, owing to the weathering of these volcanic rocks. But along the sides of the sea-lochs between tide-marks they are often well preserved. They abound on the eminence Carn Duchara, trending towards W. 20°–25° S. Kilmelfort District. (Mr. Symes.)

A few additional particulars regarding the glaciation and old sea-margins of the Island of Jura have been gleaned by MR. WILKINSON. Further evidence has been obtained by him of the westward movement of the ice-sheet by which the island was overridden. This consists both of rock-striae and of the materials of the boulder-clay. Polished and striated surfaces of rock are common at all heights. There are indications of later glaciers in the moraines that have ponded back the drainage at higher elevations, and have thus given rise to numerous small tarns. The more ancient and extensive glacial drift consists of boulder-clay, which is widely distributed, and is banked up against the sides of the higher hills. The matrix of this clay is exceedingly tough, and is often of a red colour, which bleaches white or grey on the surface. It is plentifully charged with well-rounded, sometimes striated, boulders of quartzite, Island of Jura. (Mr. Wilkinson.)

Island of
Jura. (Mr.
Wilkinson.)

epidiorite, dolerite, and red porphyry rocks, which are all found in place on the island. But there occur also pieces of red sandstone and andesite, which may have come from the volcanic district of Lorne. The west coast of Jura has long been celebrated for the number and admirable freshness of its raised beaches. To the north and south of Shian Bay they form a striking feature, also at the entrance of Loch Tarbert, and for some little distance along its northern shores. These terraces vary in elevation from the present beach up to the 200 feet contour line, which they do not pass. They consist of well-rolled shingle, which extends in patches for many miles; 90 per cent. of their stones are quartzite, which have been bleached by weathering into a dazzling white. In spite of their low elevation, they thus form a land-mark for a considerable distance at sea. They stretch out either into plateaux of bare shingle or moss-covered flats, behind which the ground rises rather abruptly along their inner margin. They extend inland in some instances for a mile. Occasionally one of the lower terraces has been a storm beach which has ponded back the drainage and now appears as a rampart of shingle with a small lake behind it.

Aberdeenshire.

Deeside. (Mr.
Cunningham
Craig.)

The survey of the high grounds in the upper part of Deeside has included the mapping of the various glacial deposits of that region by MR. CUNNINGHAM CRAIG. In the portion of the Cairngorm mountains recently examined, he has found later glaciation to be well-marked, especially in Glen Luibeg, where the moraines are noticeable for their size and regularity of form.

In the Lochnagar district, on the ridge dividing Glen Gelder from Glen Gironock, evidence of an abnormal drainage has been obtained. More than half-way up Glen Gelder, at the lowest parts of the ridge, broad flat cols may be observed. They are triangular in shape, with their apices to the eastward, where they terminate in steep dry gullies, which form the heads of small burns, that traverse the flat hollow of Glen Gironock and flow into the main stream of that valley. These gorges in the granite are not in lines of faults or crushes, and under present conditions could not have been cut by running water, as they do not drain any appreciable area. It seems probable that the explanation of them may be somewhat as follows. The ice-sheet, moving from the north-west, has overridden and completely filled the great open hollow of Glen Gelder, which probably owes its wide and shallow shape in great part to glaciation. During the decline of the cold a great mass of ice may have remained in the hollow, leaving the upper part of the glen comparatively clear, and diverting the drainage over the cols to the eastward and northward, where a similar gully is seen. Possibly a lake, or a number of small lakes, was formed in the

upper part of the glen, about the sides of the mass of ice as it melted. Drainage to the westward was barred by the high ground of Lochnagar. If such conditions were maintained for a sufficient period, the escaping water, pouring over into Glen Girnock, would have been enabled to cut the gorges referred to. The material brought down in this manner would be spread over the open expanse of Glen Girnock, which may have been in great part free from ice. In confirmation of this suggestion, it may be mentioned that the superficial deposits, which mask the hollow of Glen Girnock are almost entirely composed of granite *débris* near the western ridge. That the northern ice must have swept into Glen Gelder in great volume is proved by the numerous fragments of schistose rocks in the drift of that glen, even in its upper part, where no sedimentary rocks can be detected *in situ*. The irregular and often ill-defined morainic mounds, which are scattered over the glen, consist almost entirely of granite *débris*, and were probably formed on the surface of the ice, and were deposited as the mass melted.

Deeside. (Mr. Cunningham-Craig.)

Dumbartonshire.

While the revision already noticed (p. 38) was in progress in the district of Loch Lomond an opportunity was afforded to examine with some care the marine deposits which have long been known to exist along the margin of that lake. Attention was first called to these deposits as far back as 1823,* and their enclosed fauna has more recently been studied by MESSRS. CROSSKEY and ROBERTSON.† In his recent revision of the district MR. CUNNINGHAM CRAIG traced the deposits where they have been preserved at intervals along the western shore and on several of the islands. They usually lie below the 50 feet contour-line, but on Inch Lonaig apparently rise to 100 feet above sea level; they are much denuded and cut into by streams, and are frequently covered by river-alluvium or the present lake-beaches. Their upper part usually consists of sandy gravel, which varies in coarseness locally, and sometimes contains erratic boulders of considerable size. Underneath this coarser material a fine yellowish or grey clay frequently occurs, with a few well-rounded pebbles and marine mollusca, which are sometimes found in the position of the living organism. This clay is frequently found in a somewhat denuded state under more recent deposits, *e.g.*, at Rossarden, where it is covered by one foot of recent lake-beach gravel.

(Mr. Cunningham-Craig.)

Inch Moan and Inch Cruinn are denuded remnants of a sea-beach which apparently stretched almost across the arm of the sea, which is now Loch Lomond. Inch Tavannoch and Inch Conachan consist of several ice-worn hummocks of rock, joined

* Adamson, *Mem. Wern. Soc.*, vol. iv.

† *Trans. Geol. Soc., Glasgow*, vols. ii. and iii.

(Mr. Cunningham
Craig.)

together by and rising through these marine deposits, which are here and there breached and denuded, and cut into miniature cliffs by the wave action of the present lake.

Rossarden and the northern part of Inch Lonaig are the best localities for the marine fauna. MR. ALFRED BROWN, of Broomfield, Luss, has kindly supplied the following list of species, which he collected on Inch Lonaig and identified.

Mya truncata.
Cyprina islandica.
Pecten islandicus.
Mytilus modiolus.
Tellina tenuis.

Though the fossiliferous clay has only been observed at levels below the 50-foot contour-line, the fauna points to cold-weather conditions, and the deposits probably belong to the time of the 100-foot beach.

North of Luss no traces of the marine deposits have been observed on the western shore of the lake. It is possible that the narrower upper reaches of the Loch Lomond were occupied by ice at the time when these sands, gravels, and clays were laid down.

County Wicklow.

(Mr. Nolan.)

At such intervals as could be spared from the work of the office in Dublin, MR. NOLAN has continued the mapping of the superficial deposits in the region to the south of Dublin. He finds that the district immediately west of the high ground that extends in a southerly direction from Ballygobban south-east of Lugnaquilla mountain to the heights west of Tinahely is in general a rather flat, moory tract, gently sloping from the hills, at an elevation of from 700 to 800 feet above the level of the sea. Most of it is covered with scattered stretches of peat-bog over drift of local origin, containing pieces of granite and schist. This deposit is sandy or somewhat clayey, passing into a sandy boulder drift, which, in some of the narrow stream-courses, has been heaped up to a considerable depth. The surface is often encumbered with blocks of granite, particularly in the vicinity of Moyne Church, north of Sandy Ford, and westwards to the borders of Co. Carlow. The limestone-gravel of the plain is met with to the west at High Park, three miles north of Hacketstown, whence it extends southwards, seldom in this district attaining a greater height than about 600 feet.

On the opposite or south-eastern side of the ridge, where there is far less moor and peat-bog, the local drift is usually thicker, and forms long, smooth slopes, well cultivated, and diversified with trees and plantations. In the valley traversed by the railway, between Aughrim and Tinahely, sand and gravel prevail, and a section through these deposits showing rude stratification was noticed at Tinahely railway station. These sands and gravels are of local derivation and contain no limestone fragments,

Although the rocks in this district are chiefly granite, and consequently little calculated to retain ice-markings, yet some striae are occasionally seen. In the valley of the Ow, or Aughrim River, one mile south-east from Aghavannagh, striae may be observed that bear north and south, while at Ballymanus Hill, near Aughrim, and on the heights above Ballinglen, the trend is towards south-east. These scorings, corresponding generally with those observed in northern Wicklow, confirm the conclusion that the direction of the ice flow in this part of Leinster was southerly, inclining to south-east. (Mr. Nolan.)

RECENT. .

In the foregoing pages references have been made to some of the Recent formations met with in the course of the field-work last year. In addition to these the following brief notes are here given.

In the district of Sussex between Midhurst and Pulborough, recently mapped by MR. LAMPLUGH, it is noted that as the Lower Greensand of that tract does not afford much gravel-making material, the plateau-drift has formed the chief source of the later valley-gravels. Consequently, although terraces of erosion are sometimes well-marked along the principal valleys, there is usually very little gravel upon them except around the mouths of tributary streams which have eroded the plateau-drift. Impersistent valley-gravels occur here and there along the course of the Rother, at various elevations up to 40 or 50 feet above the present stream. Eastward, towards the junction of the Rother and the Arun, these terrace-gravels attain a wider development, and as the plateau-drift sinks to lower elevations in this direction, there is some difficulty in distinguishing between this drift and the higher patches of valley-gravel. Sussex. (Mr. Lamplugh.)

While mapping the older rocks of the south coast of Cornwall, MR. HILL has likewise traced the superficial accumulations which in post-Tertiary time have been formed more especially in the inlets by which these shores are indented. He notes that the upper parts of the tidal estuaries are mostly filled with a deposit of brown mud, formed from the decomposition of the slates, and carried seaward by streams. Amongst these deposits, that of the estuary of the River Fal calls for special notice on account of its being likely to turn out of considerable economic importance. The Fal, for part of its course, cuts through the mass of the St. Austell granite, and receives the drainage of its western portion. As this granite is in a highly decomposed condition, it readily lends itself to the processes of denudation, in striking contrast to the neighbouring slates, which, in comparison, disintegrate slowly, so that the detritus from the granite forms the principal part of the deposit. The decomposition of the felspar has resulted in the formation of deep deposits of argillaceous material, which is mixed with the sand Falmouth District. (Mr. J. B. Hill.)

Falmouth
District. (Mr.
J. B. Hill.)

and gravel of the estuary, and includes beds of impure kaolin, the deposit of which is now considerably accelerated by the drainage of the waste water from the china-clay works. This water, having a white, milky look, is charged with kaolin of the very finest texture, which has escaped in suspension. The clay of the estuarine deposit is of a white and pale yellow-grey colour. The beds of sand and gravel with which it is mixed consist of the coarser granitic detritus, and are most frequent at the head of the estuary, and along the borders of its channel. A factory has been established on the banks for the manufacture of bricks, which are largely used in the locality, and works are at present being started for the manufacture of earthenware, which, if remunerative, will create a new industry in the district. The clay suitable for this purpose extends for at least a mile along the estuary, and its thickness varies with the shelving of the bottom. It is at present being extracted to a depth of at least 12 feet below high-water mark, and this depth in many parts may be considerably exceeded.

Wicklow.
(Mr. Nolan.)

While tracing the Drift-deposits in County Wicklow Mr. NOLAN has likewise mapped the extensive tracts of peat-bog of that region. It has already been mentioned that much of the Drift in the moory uplands between Aghavannagh and Tinahely is covered with peat. A good deal of it is thin, and of poor quality, but there are some deep bogs where excellent fuel is obtained. Large tracts of peat bog cover most of the floor of the valley between Aghrim and Tinahely, that near the latter town and at Ballinglen being much utilised. A considerable extent of mountain bog caps the hill of Ballymanus, at an elevation of 1,200 feet above the level of the sea. Roots and branches of trees, especially of the common birch, are met with in these bogs.

An extensive deposit of river alluvium spreads over all the lower parts of the Aghrim and Tinahely valley, sending arms into the subsidiary valleys. As just mentioned much of its surface is covered with peat.

II. PETROGRAPHICAL WORK.

Some of the petrographical work of the Survey during the past year has been embodied in the foregoing pages in connection with the narrative of the field-work in the different districts whence the rocks examined have been obtained. But some further account of special petrographical researches has been reserved for the present section of this *Summary*. These researches have embraced both microscopical and chemical investigation. The specimens of which the investigation have been required for the purposes of the maps and memoirs of England and Wales and Scotland have been studied at this museum by MR. TEALL for the microscopical, and by DR. POLLARD for the chemical analyses. Those needed for the Irish branch of the Survey have been examined by MR. H. J. SEYMOUR at the office

of the Survey in Dublin. The chief additions to the rock collections of the Survey have been made in Scotland where the Collectors gathered 136 rock specimens in illustration of the geology of the counties of Argyll, Inverness (Skye), Ross, and Sutherland. A number of the rocks collected in Scotland by members of the staff were sliced for microscopic examination, and have been examined and described by MR. TEALL and MR. HARKER.

The total number of sliced rocks added to the petrological collection at Jermyn Street under MR. TEALL'S charge during the past year is 456. Of these 79 are English, 348 Scottish, and 29 foreign. The foreign rocks have been sliced for comparison or to assist in answering enquiries addressed to the petrological department by public institutions or private individuals. Jermyn Street Museum. (Mr. Teall.)

Detailed reports on 235 rocks have been furnished to the field officers. The remaining specimens have either been dealt with by the field officers or utilised for the purpose of labelling Museum specimens.

The English collection of rock-slides at Jermyn Street now numbers 3,265, the Scottish 8,678, and the foreign, 451.

The final revision and preparation for the press of the petrographical work on the Lewisian gneiss has been completed.

A series of microscopic slides of rocks from British Guiana, forwarded by PROFESSOR J. B. HARRISON, of the Government Laboratory, Georgetown, has been examined and reported upon.

The gradual substitution of the New for the Old Series of one-inch maps has rendered necessary the reclassification of the English petrographical collection. This has been done by MR. RHODES, assistant in the Fossil Department during the past year. All the English and Welsh rocks are now classified according to the New Series of maps.

The principal work in the Rock-room of the Jermyn Street Museum has been the relabelling of the Silurian rocks of Ayrshire and Dumfriesshire, and of the Carboniferous volcanic rocks of Scotland. This work, which has been carried out by MR. RHODES, under MR. TEALL'S supervision, necessitated the preparation of many new and thinning down of old sections, which were unsuitable for precise petrographical determination.

A series of specimens illustrating rock-structure in the Isle of Man, collected by MR. LAMPLUGH, has been added to the structure case in the rock-room.

MR. A. W. CLAYDEN, M.A., F.G.S., Principal of Exeter University College, has presented to the Museum a series of specimens of the Permian volcanic rocks of the Exeter district.

In the Dublin Office of the Geological Survey during the past year, MR. H. J. SEYMOUR has examined and reported on 234 thin slices of rocks, while 170 new slides were prepared and added to the Irish collection, which now numbers 2,351. In order to facilitate the preparation of a "rock type" catalogue, Dublin Office. (Mr. H. J. Seymour.)

he also examined and named nearly 100 slides in the collection which had not previously been determined. The report of his work, given on p. 176, is based on the examination of a number of slides selected as representative of about 750 specimens collected in the various districts referred to.

The following summaries of some of the more interesting or important researches of a petrographical kind carried on in the Survey during the past year, have been supplied by the officers who have been engaged in them :

INSOLUBLE RESIDUES OF CHALK.

(Mr. Teall.) Insoluble residues, prepared by MR. WILLIAM HILL from various horizons in the chalk, have been examined. The results are in accordance with those established by DR. HUME for the English, and by M. CAYEUX for the French Chalk. Quartz and alkali felspars are the principal clastic constituents; but whenever a sufficient quantity of material is available many heavy minerals, such as rutile, zircon, tourmaline, cyanite, and garnet may be detected.

No volcanic minerals and no traces of pumice or volcanic ash were observed; and the general character of the sedimentary material of mechanical origin, so far as composition is concerned, was found to be the same from all horizons. The amount and size of the mineral particles will be dealt with by MR. HILL as a part of his important work on the comparative petrology of the Upper Cretaceous rocks.

THE VOLCANIC ROCKS OF THE EXETER DISTRICT.

The preparation of an Explanation of Sheet 325 of the New Series of one-inch maps, embracing the district around Exeter, made it desirable that the petrography of the interesting volcanic rocks lying at the base of the red sandstone of that part of Devonshire should be more fully worked out. This research devolved on MR. TEALL, who has furnished the following summary of the results obtained by him :—

The general relations of these rocks to the sedimentary series has been described by SIR A. GEIKIE in his work on the "Ancient Volcanoes of Great Britain," and the same work contains also some particulars as to the petrographical characters of the rocks, based on observations by DR. HATCH and MR. WATTS. Further petrological details are contained in an important paper by MR. HOBSON, "On the Basalts and Andesites of Devonshire."* The general results of the re-examination may be briefly summarised as follows :—The rocks range in composition from trachytes or orthophyres to basalts or melaphyres. Many of them represent effusive forms of the minette-magma, and they

* *Quart. Journ. Geol. Soc.*, vol. xlviii. (1893), p. 496.

are thus brought into relation with the mica-trap dykes, which (Mr. Teall.) have been so well described by Mr. Collins.*

Most of them are in an advanced stage of decomposition, especially as regards the ferro-magnesian constituents. Augite is often represented by pseudomorphs in carbonate, and olivine has been converted into iddingsite or, in extreme cases, into carbonates and ferric oxide. The oxidation of the iron-bearing compounds gives a predominating red colour to the rocks. Much of this decomposition is of Permian age. It appears to be of the lateritic type so common in tropical regions, and the washing down of the red material by the Permian torrents has contributed largely to the formation of many of the basal rocks of the New Red Sandstone series.

The rock of Killerton Park near Exeter, is a biotite-trachyte or orthophyre having marked affinities with the euselite (Rosenbusch) of Rhenish Prussia and the orthophyre associated with the lower Rothliegende of Thuringia.

Another type of orthophyre containing numerous pseudomorphs of olivine occurs at Knowle, Spencecombe, near Crediton. Both these rocks have been analysed by MR. GRANT WILSON. They are closely allied to minettes in composition.

The well-known rock of Pocombe, so largely used for building in Exeter, is intermediate between orthophyre and basalt. It is composed of numerous red pseudomorphs after olivine, in a matrix composed of more or less lath-shaped microlites of felspar, a few grains of augite or carbonates after augite, and particles of iron-oxide. Both plagioclase and orthoclase are present, the relative proportion varying in different specimens. The minute and more or less altered laths of plagioclase form kernels in the orthoclase as they do in the absarokites of Iddings.†

The more typical basalts occur in the neighbourhood of Ide and Dunchideock. They frequently contain quartz, and are closely allied to the quartz-basalts of American authors. MR. HOBSON'S paper contains a full description of these rocks and a discussion as to the origin of the quartz which he regards as foreign to the magma.

In comparing the Exeter maps with their Continental equivalents, the fact that they are but feeble representatives of the Permian volcanic episode is strongly emphasised. In bulk they are insignificant in comparison with the Permian igneous rocks of Rhenish Prussia (Saar-Nahe-district), the Thuringerwald, and Les Grandes Rousses. Not only is the amount of igneous material much larger on the Continent, but the rocks are also of a much more varied character. In Rhenish Prussia quartz-porphyrries, porphyrites (andesites) and melaphyres (basalts) occur in great abundance and in rich variety. Under these circumstances, it is interesting to note that the Permian breccias of

* *Jour. Roy. Inst., Cornwall*, part ii., vol. iii. (1884).

† Absarokite-shoshonite-banakite series. *Jour. Geol.*, vol. iii., p. 935.

(Mr. Teall.) South Devon contain, as MR. WORTH has shown, quartz-porphyrines, rhyolites, spherulitic felsites, and andesite in addition to the rocks above described. The Exeter traps and the Permian breccias taken together probably contain representatives of all the Continental types occurring on this horizon.

CHEMICAL INVESTIGATION OF ROCKS AND MINERALS.

The work of the chemical laboratory at the Jermyn Street Museum has continued to make good progress. DR. POLLARD was instructed, in addition to his duties there, to visit the officers in the field in South Wales in order to study on the spot the phenomena of dolomitization which are developed in the Carboniferous Limestone of that region. Accordingly, he studied these phenomena in the district of the Mumbles and collected material which awaits further treatment. He has conducted in the laboratory a series of quantitative analyses, and has likewise made a considerable number of qualitative examinations for petrographical purposes, or the identification of specimens. He has furnished the following notes of some of the more important researches on which he has been engaged :—

Tertiary volcanic rocks of Skye. (Dr. Pollard.)

During the course of his survey of the Tertiary volcanic region of the Island of Skye, MR. HARKER has met with groups of rock of which it was highly desirable to know the complete chemical composition. He accordingly selected the following series of typical specimens, and submitted them for investigation by DR. POLLARD. The results of the inquiry are here given :—

[7064.] Granophyre, hornblendic, of Beinn a' Chairn sheet, in tributary of Allt Braigh Bhlaigh, 1,200 yards south-west of triangle on Beinn a' Chairn.

[8057.] Olivine Basalt (sill), Brochbeinn, 500 yards north of small tarn and south-east of larger loch.

[8043.] Olivine Gabbro, west bank of Sligachan River, just below junction with Allt Coire Riabhaich (the northerly burn of that name).

[8191.] Gabbro, Coire a' Mhadaidh.

[7124.] Hornblendic Granophyre, typical drusy variety, south end of Druim Eadhan Da Choire, west side of Coire na Aulg.

[8185.] Olivine Basalt (lava), Allt Feionn Fharaidh, Drynoch.

[7854.] Olivine Diabase, sill in bedded basalt lavas, summit of Ben Lee.

[7862.] Porphyritic Olivine Dolerite or Basalt, 7 feet dyke cutting granite on south-east slope of Ciche na Beinne Deirge.

Nos. 7064, 8057, and 8043 were analysed in detail (most of the ingredients mentioned by CLARKE and HILLEBRAND* being looked for). The analytical methods used were those described by these chemists. The remaining five rocks were not analysed in

* *Bull. U. S. Geol. Survey*, No. 184.

quite so much detail, very small quantities not being determined quantitatively.

Tertiary volcanic rocks of Skye. (Dr. Pollard.)

Special precautions were taken as to the purity of reagents, and it was occasionally found necessary to purify some of them. Potassium bisulphate was always prepared in the laboratory owing to the difficulty of obtaining it of a satisfactory quality. Again, hydrofluoric acid has always been redistilled with permanganate before ferrous iron determinations. As it was suggested that some of the rocks from Skye contained metallic iron, Nos. 8057 and 8043 were examined for it by treating with a strong solution of mercuric chloride. The samples for this examination were crushed roughly, wrapped in cartridge paper to avoid any chance of contamination with iron. After all paper scraps had been picked out with care, the coarse powder was crushed and finally ground to a very fine powder in an agate mortar.

Blind experiments with rock-powder + a small weighed quantity (.05 to .1g.) of pure iron wire were made. These gave good results [the greatest deviation being .0771g. Fe taken = .0763g. found], and as 2 to 5g. of rock-powder were taken, the error would be negligible. No iron could be detected in either of these rocks. It might, however, be of interest at some future time to examine a larger number of gabbros and basalts from Skye.

	7064.	8057.	8043.
S.G.	2.63	2.91	2.85
SiO ₂	71.98	16.13	46.39
TiO ₂	.37	3.60	.26
ZrO ₂	—	Trace?	—
Al ₂ O ₃	13.13	17.07	26.31
Fe ₂ O ₃	1.33	6.61	2.02
Cr ₂ O ₃	—	Trace?	Trace
FeO	1.64	8.20	3.15
MnO	.14	.28	.14
CaO	1.15	7.15	15.29
BaO	Trace	—	—
MgO	.56	4.38	4.82
K ₂ O	4.93	1.19	.20
Na ₂ O	2.98	3.58	1.63
P ₂ O ₅	.19	.09	Trace
Cl	Trace?	—	—
H ₂ O 105°	.39	.59	.10
H ₂ O above	1.38	1.71	.48
Total -	100.17	100.58	100.82

[NiO, CoO, Li₂O, S, F were not found.]

Tertiary volcanic rocks of Skye. (Dr. Pollard.)

—	8194.	7124.	8185.	7854.	7862.
S.G.	2.90	2.66	2.87	2.85	2.95
SiO ₂	47.28	70.34	46.61	45.24	44.01
TiO ₂	.28	.46	1.81	2.26	1.66
Al ₂ O ₃	21.11	13.28	15.32	15.63	12.69
Fe ₂ O ₃	3.52	2.65	3.49	5.56	3.62
Cr ₂ O ₃	—	—	Trace	Trace	Trace
FeO	3.91	2.24	7.71	7.19	8.75
MnO	.15	.19	.13	.23	.21
(CoNi)O	—	—	Trace	Trace	Trace
CaO	13.42	1.24	10.08	9.38	10.57
MgO	8.06	.40	8.66	7.82	12.86
K ₂ O	.29	4.90	.67	.72	.49
Na ₂ O	1.52	3.61	2.43	2.01	1.68
P ₂ O ₅	Trace	Trace	Trace	.20	.17
CO ₂	—	—	Trace	.49	Trace
S	—	—	—	—	.11
H ₂ O 105°	.13	.46	1.10	1.12	.89
H ₂ O above 105°	.53	.76	2.07	2.21	2.73
Total	100.20	100.53	100.08	100.06	100.44

No. 7124 contains a trace of BaO and Li₂O.

Culm-measure manganese. (Dr. Pollard.)

An analysis of a manganese deposit of Culm Measure Age from a limestone quarry, Hookworthy, Devonshire, gave the following results:—

Res. insol. in concentrated hydrochloric acid	64.64
CuO	.15
Fe ₂ O ₃	13.10
Al ₂ O ₃	.72
(NiCo)O	.11
MnO	9.98
CaO	.55
MgO	.20
O (Peroxide Oxygen)	2.05
H ₂ O at 105°	5.72
" above 105°	3.21
Total	100.43

The insoluble residue is composed of—

SiO ₂	63.3	{ of which 2.0% is colloid silica.
Fe ₂ O ₃	.2	
Al ₂ O ₃	.9	
CaO	.3	
	64.7	

The substance was a dark-brown friable powder which required no grinding, but only thorough mixing to get a uniform sample.

The small quantities of copper, nickel, and cobalt are interesting, as traces of these ingredients were found in the manganese nodules described in the "Challenger" reports. Culm-measure manganese (Dr. Pollard.)

MR. TEALL gives the following account of this specimen:—
 "The specimen analysed by DR. POLLARD was collected by me, from a Limestone Quarry in the Lower Culm series close to the village of Hockworthy, Devonshire. It was taken from one of several black bands, measuring two or three inches in thickness, regularly interstratified with grey shales, and apparently overlying the limestone. The insoluble residue is a fine white powder, mainly composed of cryptocrystalline silica in minute grains and irregular amorphous patches. A few grains of quartz measuring less than 1 mm. in diameter, and probably of elastic origin occur, but the amount of mechanical sediment is extremely small. The cryptocrystalline silica is probably of organic origin. The specimen was analysed in the hope that it would be found to be much richer in oxide of manganese than actually proves to be the case. The limestone in the same quarry is dark, bluish-grey, and finely crystalline. Cherty portions of this limestone consist of cryptocrystalline silica associated with calcite which often takes the form of idiomorphic rhombs."

A sample of the clay already referred to as deposited in the estuary of the Fal and as probably of economic importance was sent up by MR. HILL. It was taken from a ford across the Fal, half a mile west of Ruar Lamhorne. A complete analysis of the clay gave the following results:— Falmouth Clay Deposit. (Dr. Pollard.)

AIR DRIED SAMPLE.

SiO ₂	-	-	-	-	-	-	-	49.67
TiO ₂	-	-	-	-	-	-	-	.19
Al ₂ O ₃	-	-	-	-	-	-	-	33.43
Fe ₂ O ₃	-	-	-	-	-	-	-	1.92
CaO	-	-	-	-	-	-	-	Trace
MnO	-	-	-	-	-	-	-	Trace
MgO	-	-	-	-	-	-	-	.37
K ₂ O	-	-	-	-	-	-	-	3.32
Na ₂ O	-	-	-	-	-	-	-	.29
Li ₂ O	-	-	-	-	-	-	-	Trace
SO ₃	-	-	-	-	-	-	-	.07
Cl	-	-	-	-	-	-	-	.37
H ₂ O 105°	-	-	-	-	-	-	-	1.30
H ₂ O above 105° + some organic matter	}							9.64
								100.57
Less O for Cl	-	-	-	-	-	-	-	.17
Total	-	-	-	-	-	-	-	100.40

The chlorine and sulphuric acid are due to sea water.

The soluble salts amounted to .83 per cent., the sand + acid silicates to 24.7 per cent.

Among the rocks met with by MR. CLOUGH in the Glenelg district is an eclogite, regarding the chemical constitution of one of the minerals of which further information was desirable. Accordingly from a specimen sent up for examination by MR. Eclogite of Glenelg. (Dr. Pollard.)

Eclogite of
Glenelg. (Dr.
Pollard.)

CLOUGH the garnet was separated and analysed. The locality given by MR. CLOUGH for the specimen is " $\frac{1}{2}$ mile + 60 yards slightly east of north of Beinn a Chapuill," and the following is MR. TEALL's description:—

"[8449.] Medium-grained dark coloured massive rock, composed of garnet and omphacite, with rutile as an unimportant accessory. This rock is a typical eclogite."

The specific gravity of the garnet was 3.74, the composition as follows:—

SiO ₂	-	-	-	-	-	-	-	40.3
TiO ₂	-	-	-	-	-	-	-	Trace
Al ₂ O ₃	-	-	-	-	-	-	-	21.6
FeO	-	-	-	-	-	-	-	18.0
Fe ₂ O ₃	-	-	-	-	-	-	-	1.3
MnO	-	-	-	-	-	-	-	.7
CaO	-	-	-	-	-	-	-	7.2
MgO	-	-	-	-	-	-	-	11.2
Total -								<u>100.3</u>

Rock
analysis.
(Mr. Grant
Wilson.)

During the winter of last year MR. GRANT WILSON in Edinburgh made eleven analyses of rocks. The details of these investigations will appear in the memoirs of the Survey.

PETROGRAPHICAL RESEARCH IN IRELAND.

Reference has already been made in previous pages (pp. 71-81), to the petrographical assistance given by MR. H. J. SEYMOUR to the officers who have been engaged in revising the Silurian areas of the south-east of Ireland. The following more detailed and connected summary of his observations has been prepared by him.

Silurian
Rocks West
of the Lein-
ster Granite.
(Mr. Sey-
mour.)

In the account of the work of the Geological Survey for 1898* a brief statement was given of some general results of a preliminary examination of the igneous rocks and so-called "ashes" in the district lying to the west of the range of the Leinster granite. Early in the past year a more detailed investigation of the rocks of that district was made (Sheets 111, 112, 120, 128, and 129 of the one-inch map), which has confirmed the conclusion that the so-called ashes in this district, which occur within a zone about a mile in width next the granite, are really more or less metamorphosed basic igneous rocks, while those which lie further west are without exception schistose grits or greywackes. The main road which starts just north of "Brittas Big" (top of Sheet 120) and runs southwards through Blessington, Poulaphuca, Annaleeky, and Stratford, may serve as boundary line between the two classes of rock. The grits (greywackes) belong to one type and vary only in degrees of coarseness; most of them show a schistose structure. A thin section of a coarse variety, such as occurs near Poulaphuca, is seen under the microscope to consist essentially of quartz-

* *Summary of Progress for 1898*, p. 64.

grains, showing strain-structure, and forming eyes which are wrapped round by shaly bands of a greenish (chlorite) colour. Pieces of plagioclase crystals are almost always present, but only sparingly: and also rounded and lenticular fragments of finely crystalline basic rocks of the andesite type. The average diameter of the quartz-grains and other component fragments is nearly 4 mm. for this coarse variety, but elsewhere descends to microscopical dimensions.

Silurian
Rocks West
of the Lein-
ster Granite.
(Mr. Sey-
mour.)

The igneous rocks which have been mapped as "ashes" may be classed together as altered basic andesites (frequently porphyritic) or dolerites without olivine. Where they lie close to the granite mass, they have been metamorphosed into hornblende-schists and amphibolites, while their outcrops at a greater distance appear as mostly epidiorites. This latter type is extensively developed in the north-east corner of Sheet 120 and in the adjoining areas in Sheets 111 and 112. The rock (I. 1848) at Ballinascorney Gap (Sheet 112) may be regarded as representative. It is an altered dolerite of medium grain. Though it looks fairly fresh in the hand-specimen, yet in section the ferro-magnesian mineral is seen to be mainly of secondary origin. The felspars occur in rather fresh lath-shaped sections which are repeatedly twinned. The interior of the crystals of felspar is more basic than the exterior and extinguishes at a higher angle, the passage between the two being sometimes quite gradual and occasionally abrupt. The central portion seems to be labradorite, while the exterior corresponds probably to andesine. The porphyritic constituent is a felspar too highly altered for determination. The augite when fresh is of a pale, reddish-brown colour, but it is for the most part altered into a greenish hornblende. It forms rounded grains, and sometimes fairly large crystals in which the felspar laths are set ophitically. Skeleton crystals of ilmenite occur, but no olivine could be detected.

The hornblende-schists and amphibolites are of the usual type, and call for no special remark. They are extensively developed in the district, and no doubt represent originally pyroxenic varieties. Near Colvinstown a basic mass (Ds, "Greenstone-ash" on Map) occurs, completely surrounded by granite, which sends numerous veins into it. A hornblende-schist which is seen here is composed of alternating narrow bands of actinolite and feldspathic material, the whole rock being much folded and contorted. Near Donard (Sheet 129) an interesting outcrop occurs illustrating the effects of dynamo-metamorphism. Ballymooney Hill, north of Donard, and Deerpark Hill, south of the same place, are composed of a coarsely porphyritic rock mapped as "Greenstone-ash." Sections prepared from different parts of the masses show the following characteristics:—

Slide I. 1860 (Deerpark Hill) is the least altered of the series of rocks, but at the same time is considerably metamorphosed as compared with its original condition, when it was most probably a porphyritic basic andesite or aphanite, similar to the well-known Lambay porphyry. In the hand-specimen the por-

Silurian
Rocks West
of the Lein-
ster Granite.
(Mr. Sey-
mour.)

phyritic plagioclases, which stand out conspicuously on a weathered surface, either singly or in groups of several individuals, form stumpy, flattened prisms of all sizes up to about 2 cm. $\times$ 1 cm. $\times$.5 cm. They seem fairly fresh, show parallel twin striae, and are brownish in colour, owing to various inclusions. In section the ground is mostly made up of minute brown mica-flakes (secondary biotite), along with some uralitic hornblende, embedded in a clear granular feldspathic mosaic. Both the mica and the hornblende are oriented in the same direction by pressure, which has given the ground a schistose structure, and caused it to flow round the porphyritic plagioclases, and even penetrate them along cracks. The feldspars are much clouded by opaque whitish inclusions. In all cases they show strain-slip, and are usually surrounded by a mylonitic envelope derived from themselves. Chlorite and iron-ore are present, but sparingly. Alteration is too far advanced to determine the plagioclase, but the presence of secondary calcite would seem to indicate a lime variety, very probably labradorite. (This is the feldspar in the Lambay rock.)

I. 1861 shows a further stage in the metamorphism of the rock. The bronzy brown mica is still more conspicuously developed. Hornblende is practically absent, and the feldspars are beginning to assume a parallel position with regard to one another. Continued strain has made the fragments into which they were broken slide over one another, producing schistose feldspathic zones along the gliding planes, and also wavy extinction under crossed Nicols. Weathered specimens now show the feldspars up to 3 cm. in length, but with the cross section considerably reduced in area, and arranged with their longest axes parallel to one another, and to the direction of schistosity.

I. 1862 is practically identical with the last, but contains some apatite. The plagioclases become more and more elongated, till the original stumpy crystals are drawn out into lenticles up to 8 cm. long, 1 cm. wide, tapering at each end, and from 1 to 1.5 mm. thick.

I. 1859 is a section of a rock in this stage which is accompanied by the formation of numerous secondary minerals. The brown mica occurs in knots, the individual crystals of which are considerably larger than usual. The feldspar has partly recrystallised in water-clear granules, whilst most of the area formerly occupied by it is now crowded with minute prisms of epidote and zoisite. The original ilmenite is represented by sphene which occurs in numerous strongly pleochroic reddish crystals. In this final stage the rock is a banded gneiss or schist composed of white (feldspathic), and dark (biotite) bands. The light bands vary in dimensions, according as they represent a single crushed feldspar or a group of several individuals, being naturally larger in the latter instance. This case is a remarkably clear demonstration of the effects of metamorphism, and seems to throw some light on the production of banded gneisses. Although the outcrops occur close to the granite mass, no evidence of injection of the latter rock into the basic variety was noticed in this particular case.

With such clear evidence of pressure metamorphism, there can be little doubt that the hornblende-schists in this locality owe their origin to the same cause, especially as many of them are obviously crumpled and contorted (*e.g.*, at Colvinstown).

The revision of the igneous rocks in county Wicklow was continued during the year, and some eighty-five slides from Sheet 130, and forty-two from 139 were examined and reported on. Many of the felsites are compact, schistose, and altered; so that their determination is rather difficult and unsatisfactory. As the microscope frequently fails to give much assistance, reliance has to be placed entirely on the field-evidence and on physical and chemical observations. The varieties met with include potash- and soda-felsites, diabases, diorites, dolerites, and basalts, all of which occur both in the uncrushed and crushed condition. The felsites vary much in physical characters, often closely resembling cherts. Thin sections, however, usually reveal the presence of minute plagioclases, in a ground presenting a devitrified aspect. Soda-felsites or keratophyres frequently occur in the area examined. They appear to be the latest rocks in the igneous series, as where typically developed they penetrate the ordinary (potash) felsite, which is known to be later than the basic rocks with which it is associated.

Reference has already been made to the field-observations by MESSRS. EGAN and MCHENRY regarding the occurrence of a remarkable brecciated structure in some of the intrusive felsitic rocks in the East of Ireland. MR. SEYMOUR contributes the following description of one of these which appears near Rockfield House, on the shore south of Wicklow Head. (Sheet 130, I. 1760 and 1761.) Here a greenish trachytic (soda) felsite is seen to penetrate, in numerous veins, a pale-coloured felsite, somewhat more acid perhaps in composition, and which weathers to a pinkish colour. The older rock has been shattered and in one part of its mass, occurs in angular fragments embedded in a greenish base composed of the later intrusive rock, the whole forming an eruptive or intrusive breccia. Continued pressure has subsequently fractured both this base and the included fragments. Microscopically, the greenish "ground" is remarkable. It contains numerous clear fragments (devitrified glass) with concave outlines and hour-glass forms, exactly similar in appearance to the lapilli of volcanic glass so characteristic of tuffs. Figure 48, p. 262, in Rosenbusch's "Elemente der Gesteinslehre" exactly represents the structure developed in the ground of this rock, and could have been drawn from a thin slide of it. There can be little doubt here, however, that the tuff-like structure has been produced by the brecciation in situ of the intrusive veins which had consolidated in a glassy condition, the resulting pieces of fractured glass being similar in shape to volcanic lapilli. Similar "intrusion breccia" occurs also at Arklow Head, Co. Wicklow, where a brecciated rock undoubtedly behaves as a dyke. It consists of pieces of lavender-grey felsite, embedded in a greenish porphyritic and brecciated soda-felsite, the phenocrysts being albites and soda-orthoclase. Though these crystals show evidence

County
Wicklow.
(Mr. Seymour.)

County
Wicklow.
(Mr. Seymour.)

of being fractured in situ, it is remarkable that in one of the slides an irregularly-shaped piece of pumice occurs, which could hardly have escaped destruction if it existed during the period of strain to which the rock has certainly been subjected. It seems difficult to account for its presence unless it be regarded as of secondary origin, and possibly somewhat analogous in its formation to the pumice which BERGEN and BEUDANT have shown to be occasionally formed when volcanic glass is gradually fused in a Bunsen flame. The light coloured felsite-fragments, which occur as inclusions, contain sphene, and this has given rise to anatase, which in some of the rocks abounds in crystals of minute size.

As mentioned in last *Summary of Progress*, the rocks mapped as tufts (Fs or Ds), to the east of the Leinster granite, were found to be sheared varieties of acid and basic rocks respectively. This has again been found to hold for all the ground examined last year. Up to the present no true tuft of any description has been met with in County Wicklow (Sheets 130 and 139).

County
Waterford.
(Mr. Seymour.)

Some account has been given at p. 79 of the igneous rocks of the coast of Waterford, mapped last year by MR. KILROE. Their petrography has been partly studied by MR. SEYMOUR, who during a visit to the ground with MR. KILROE collected a representative series of the rocks. These have subsequently been examined microscopically, and have been found to be in general similar to those in County Wicklow. Typical soda-felsites occur, some of which in the field closely resemble basic rocks. In section these are seen to be very trachytic in structure, they contain orthoclase (soda ?) phenocrysts, embedded in a crystalline felt of felspar microlites, showing flow-orientation. Secondary chlorite is also present in the slides. The soda-felsite at Ballydowane Bay seems to approach to the pantellerite type. The felsites also frequently show beautifully developed flow, perlitic, and spherulitic structures, being thus rather a contrast to the Wicklow specimens, where these characteristics are only rarely met with.

Another peculiar feature in the rocks of this district is the abundance of secondary epidote which many of them contain. This mineral often forms close on 40 per cent. of the bulk of some of the sedimentary rocks; it also occurs in oval concretions up to 3 in. in longest diameter in a crystalline rock, apparently an altered andesite, near Carrickbarrahane House. A coarsely porphyritic felsite occurs near Ballyvoyle Railway viaduct, containing well-formed, reddish-coloured orthoclase crystals in a greenish felsitic base. The andesites in this area are usually much altered, and the porphyritic mineral, when present, is augite, and not a felspar, as is usually the case in more northerly localities.

Coast of
County
Down. (Mr.
Seymour.)

As already stated, MR. SEYMOUR accompanied MR. EGAN to the east coast of Co. Down, in order to revise the igneous geology of that district (Sheets 37, 38, and 49). Almost every outcrop was visited by them, and a representative series of specimens was collected. These have now been sliced and

examined by MR. SEYMOUR, who finds them to be all lamprophyres, the varieties differing from one another in the fact that the predominating ferro-magnesian constituent is sometimes biotite, sometimes hornblende, less often augite. In the last case the augite accompanies the biotite or the hornblende, but does not occur to the exclusion of either of these minerals. The felspar, as is usual in these rocks, is much altered and calcified, and is on the whole plagioclase, though a little may be referred doubtfully to orthoclase. The mica varieties are, therefore, Kersantites and augite-Kersantites, and the hornblende varieties Camptonites and augite-Camptonites

Coast of
County
Down. (Mr.
Seymour.)

One of the rocks occurring as a dyke on the shore of South Bay, 3 miles E. of Portaferry (Sheet 49) is specially noteworthy. It is a hornblende-kersantite containing a blue amphibole, allied to riebeckite or arfvedsonite. It belongs to a class of minerals (soda-amphiboles) not hitherto known to occur *in situ* in Ireland, and is now recorded for the first time. The mineral in question occurs as a secondary addition to the terminal edges of the primary green hornblende. A nearly identical occurrence has been described by DR. WHITMAN CROSS in the case of a rock from Colorado.*

An examination of the interesting rocks of the Ox Mountains undertaken by MR. SEYMOUR last year was continued at intervals. Owing, however, to the necessity of completing more urgent work it was not found possible to examine more than a small part of the collection. It is hoped that during the present year the work may be resumed and extended. The varieties examined included felspathic eclogites, garnet amphibolites, schistose diorites, biotite- and hornblende-gneisses, and granites with microcline. They are similar to the rocks described by MR. TEALL from the Ballyshannon area, in the Appendix to the Memoir on the Sheets 31 and 32.

Ox Mountain
District. (Mr.
Seymour.)

During his visits to the field in the past year MR. SEYMOUR took a number of photographs of geological interest. One series illustrates some of the typical features exhibited by the rocks along the coast of Waterford, from Stradbally to Annestown. Copies of these are preserved in the office for reference. Some photo-micrographic work has also been done during the year in the case of slides of special interest in the Irish petrographical collection.

Photographic
Work. (Mr.
Seymour.)

III.—PALÆONTOLOGICAL WORK.

The Palæontologists of the Geological Survey at Jermyn Street have charge not only of the palæontological work of the Survey, but also that of the Museum. They determine all fossils collected by the staff in England and Wales and Ireland. The Scottish palæontological work is done at the Survey Office in

* *American Journ. Science*, vol. xxxix., p. 359.

Edinburgh. MR. E. T. NEWTON has supplied the following notes of the more important examinations made by him and his staff last year.

MUSEUM, JERMYN STREET.

The constant need of revision and rearrangement of the fossils exhibited in the Museum of Practical Geology, as well as their maintenance in a satisfactory condition, together with the specific determination of such fossils as are presented, received from the field officers, or obtained from other sources, necessarily occupies the greater part of the time of the Palæontological Department. This routine work, however important in itself, is not usually of such a nature as to call for any special remarks; but it may be mentioned that of the fossils received during the year, a large part has already been specifically determined by DR. F. L. KITCHIN, who has likewise named a series of Carboniferous Limestone Cephalopoda, from the Isle of Man, kindly lent to the Survey by MISS BIRLEY and MR. ROBT. LAW, to whom our thanks are due for their courteous assistance. We have also to acknowledge our indebtedness to MR. G. C. CRICK of the British Museum for his valued help in the determination of these Cephalopoda.

The results of much of the detailed work of the past year will be seen in the Memoir by MR. A. J. JUKES BROWNE on the Gault and Upper Greensand, and in that by MR. G. W. LAMPLUGH on the Geology of the Isle of Man, now in the hands of the printer, as well as in other Memoirs which have appeared during the year.

The revisions and rearrangements which have been made in the Museum have chiefly been the work of MR. H. A. ALLEN, who has also named a large number of the new fossils added to the collection. The need for a catalogue of the many valuable *figured* specimens contained in this Museum has long been felt; but the pressure of other work has hitherto prevented its being attempted. A beginning, however, has been made by MR. ALLEN, who has prepared a catalogue of the *figured* specimens from the Eocene and Oligocene formations. This catalogue includes many of the Types described by PROF. MORRIS in FORBES'S "Tertiary Fluvio-marine Formations of the Isle of Wight"; by PROF. FORBES, in "Note on Fossil Leaves from Ardtun"; by DE LA HARPE and by MR. STARKIE GARDNER, in their works on the Plant Remains of the Isle of Wight and of the South Coast. (See Appendix to the present volume, p. 195.) Although but a small instalment, it will serve to show the nature of the work; and being complete, so far as it extends, will, it is believed, be found useful to those working at Tertiary Palæontology.

Three series of Graptolites have been received from the Irish Survey, and reported upon by MR. NEWTON. One series was from numerous localities in the Keeper Hill district. The chief forms noticed were of the *Monograptus Flemingi* and *M.*

Hisingeri types, with some indistinct specimens which appeared to be *Cyrtograptus hamatus*, thus indicating beds of Wenlock or Tarannon age. A few specimens from a cutting on the Waterford, Dungarvan, and Lismore Railway proved to be *Diplograptus* allied to *D. pristis*, and probably indicate the presence of Llandeilo rocks at this place.

A second series from Ballyhelly, Co. Clare, too poorly preserved to give positive evidence, seemed to include *Monograptus Flemingi* and *M. priodon*, making it probable that the beds are of Upper Silurian age, and perhaps Wenlock.

A third series, chiefly from the neighbourhood of Belvoir, Co. Clare, were apparently from one horizon only. The absence of any Monograptids made it unlikely that these beds were of Upper Silurian age, and as there were no examples of Didymograptids they could scarcely be so low as Lower Llandeilo. The forms recognised were *Diplograptus pristis*, *D. foliaceus*, *Climacograptus scalaris*, and *Glossograptus Hincksi*, all species of Glenkiln or Hartfell age. It seems almost certain, therefore, that the strata belong to the Lower Bala or Upper Llandeilo series.

Application is constantly being made to this Department for assistance in work of a palæontological nature, and the officers do their best to render such help as is possible. As examples of this co-operation the following cases may be mentioned:—

SIR THOS. WARDLE, of Leek, desired information respecting a series of bones, which he had unearthed while exploring a cave at Red Hurst, near Wetton. Two consignments of these remains were examined by MR. NEWTON; they proved to be largely human and of comparatively modern origin; perhaps Romano-British, or Neolithic; but there were indications of Pleistocene gravels underlying the more modern deposits. An account of this cave was published by SIR THOS. WARDLE in *The Leek Post*, February 25, 1899.

A collection of bones from a deposit at Skitts Hill, Braintree, Essex, was critically examined by MR. NEWTON, at the request of the Essex Field Club, as it was deemed desirable to have the specific identification of the bones verified before publication. An account of these remains is included in a paper by the REV. J. W. KENWORTHY on this "Supposed Neolithic Settlement at Skitts Hill," just published in the *Essex Naturalist*.

A series of fossil shells and rocks was received from JUDGE MIDDLETON of Nicosia, Cyprus, through the secretary of the Royal Societies' Club. The rocks were examined by MR. TEALL, and the fossil shells by MR. NEWTON. The deposit from which the shells were obtained appears to be of late Pliocene age. Among the species recognised were many like those found in similar deposits in Italy and Sicily, as well as at other places around the Mediterranean coasts.

The Museum collection of fossils has been largely made use of by workers for the purpose of illustrating their Memoirs, and many specimens have been figured in various publications, as shown in the subjoined list of figured specimens published during 1899:—

Specimens figured in the Palæontographical Society's volume for 1899, by PROF. RUPERT JONES and DR. H. WOODWARD in their "British Palæozoic Phyllopoda":—

Gastric teeth of Dithyrocaris.
Dithyrocaris tricornis, Scouler.
 „ *Colei*, Portlock.

Specimens figured in the Palæontographical Society's volume for 1899, by DR. WHEELTON HIND, in the "British Carboniferous Lamellibranchiata":—

Edmondia oblonga, Portlock.
 „ *laminata*, Phillips. Two specimens.
 „ „ var. *sublævis*, Hind.
 „ *scalaris*, M'Coy.
 „ *MacCoyi*, Hind.
Scaldia benedeniana, de Ryckholt.
Cypricardella parallela, Phillips.

Specimens figured in the Palæontographical Society's volume for 1899, by HENRY WOODS, Esq., in his "Cretaceous Lamellibranchiata of England":—

Nucula spectonensis, Woods.
 „ *pectinata*, Sow. var. *crete*, Gardner.
 „ *obtusa*, Sow. Two specimens.
 „ *albensis*, d'Orb.
Anomia lævigata, Sow. Three Specimens.
 „ cf., *pseudoradiata*, d'Orb.
Barbatia marullensis, d'Orb. Two specimens.
Grammatodon carinatus, Sow.
Isourca obesa, d'Orb.
Pectunculus sublævis, Sow.
 „ *umbonatus*, Sow.

Specimens figured by Dr. A. SMITH WOODWARD, in the "Proceedings of the Geologists' Association," vol. xvi., 1899:—

Notidanus serratissimus, Agassiz.

Specimens figured by E. T. NEWTON in the "Quarterly Journal of the Geological Society, London," vol. lv., 1899:—

Amia anglica, Newton.
 „ *Colnutti*, Newton.
Zanclodon cambrensis, Newton.
Mustela robusta, Newton.

Specimens figured by Miss DONALD in the same journal:—

Hormotoma ? gracillima, Salter.
 „ ? *dubia*, Donald.

Specimens figured by H. BOLTON, Esq., in the "Memoirs of the Manchester Literary and Philosophical Society," vol. xliii., 1899:—

Palæochorda minor, M'Coy. Three specimens.
 „ *major*, M'Coy.
Chondrites informis, M'Coy. Three specimens.

SCOTLAND.

The Palæontological Department in Scotland has been carried on as hitherto by MR. B. N. PEACH, assisted by MESSRS. A. MACCONOCHIE and D. TAIT. As usual the collections made during the year, after a preliminary investigation by MR. PEACH, have been partly distributed among specialists for identification and

description. Thus DR. TRAQUAIR has determined the fish-remains, MR. KIDSTON has undertaken the naming of the plants, MR. KIRKBY has examined the ostracods while DR. J. WHEELTON HIND has examined the lamellibranchs.

The number of fossils gathered by the Survey Collectors in Scotland during 1899 amounted to 913. These comprise 479 specimens from the Cambrian rocks of Skye, Sutherlandshire, &c.; 20 from the Ludlow rocks of Lanarkshire; 112 from the Downtonian strata of Ayrshire and Lanarkshire; 8 from the Lower Old Red Sandstone of Arran; 39 from the Carboniferous Limestone of Arran; 99 from the Coal-measures of Arran and Dumfries-shire; 154 from the Jurassic rocks of Skye, and 2 specimens from Islay.

MR. PEACH has supplied the following digest of the palæontological work of the staff in Scotland for the past year.

Torridonian.—In view of the forthcoming Memoir on the North-West Highlands a further determined search was made by MESSRS. MACCONOCHIE and TAIT in the Torridonian rocks of Skye, chiefly in the dark carbonaceous Shales of the Kinloch sub-division of the Diabeg group. Though the material searched seems eminently favourable for the preservation of organisms, as ripple-marked and rain-pitted surfaces are plentiful, no vestige of a fossil was obtained. The same collectors also made another exhaustive search of the dark calcareous shales of the Cailleach Head in West Ross-shire, the highest visible members of the formation. The only indications of life they there exhumed are some doubtful specimens of annelid castings ("Worm pipes,"), but these are not sufficiently definite for identification. The shales of the Diabeg Group at Stoer in West Sutherland, which had already afforded some traces of organisms, were also searched bed by bed with the result that only the curious radiating bodies resembling some sponge spicules were obtained. The further study of some of the specimens, however, throws some doubt upon the organic character of these bodies. They may not be organic, but may be due to aggregations of crystals that had formed in the clays before their consolidation, but had been subsequently dissolved out and replaced by calcite. It is unfortunate that hitherto the Survey Collectors have been able to obtain no more definite organic remains than "worm pipes" from these practically undisturbed sediments.*

Cambrian.—A further collection of fossils was made by MESSRS. MACCONOCHIE and TAIT from the Durness limestones and dolomites in the Strath district of Skye. The search was made chiefly for the purpose of obtaining remains of trilobites

* Since the above notes were written, certain phosphatic nodules occurring in the dark micaceous shales at Cailleach Head have been examined by MR. TEALL. From their chemical composition these nodules are presumably of organic origin, an inference which is confirmed by the fact that MR. TEALL has determined under the microscope certain spherical cells and brown-coloured fibres in them, which appear to be débris of organisms.

(Mr. B. N.
Peach.)

that might have a zonal value for the determination of the exact geological horizon of the members of the Durness Limestone series. Although a considerable collection of fossils was obtained no trilobite remains were found among them. The fossils add little or nothing to the list furnished in last year's *Summary*. A search was likewise made in the Durness area of Sutherland, where the collectors succeeded in finding several fragments of trilobites. From the preliminary study of the material thus acquired, the fossils would seem to indicate that the Croisapuill group of the Durness Limestone, the bed in which they chiefly occur, is of Middle or Upper Cambrian age—a conclusion to which the study of the other fossils from this band has already led.* Fragments of *Olenellus* were obtained from the cleaved 'Fucoid Beds' near Heilim, on Loch Eireboll, by MESSRS. MACCONOCHIE and TAIT. This is the first record of trilobites from this region, which is classic in the history of the rocks of the North-West Highlands.

Silurian.—A further search was made by MR. TAIT in the Ludlow and Downtonian rocks of Ayrshire and Lanarkshire, with the result that fragments of the fish *Birkenia elegans*, hitherto only obtained from the Downtonian rocks, was got in the *Ceratiocaris*-band of the Ludlow rocks on the Logan water above Lesmahagow. The materials obtained from the Downtonian rocks have been studied by DR. TRAQUAIR, and the results have been embodied in a paper published by him.† He remarks that, "Two additional specimens of *Lasanius*, collected by MR. TAIT at Seggholm since my notes at p. 567 were in type, indicate a new species distinguished from *L. problematicus* by the considerably greater proportional size and length of the spurs or thorns borne by the median scutes, and which I propose to designate *Lasanius armatus*. In one of these two examples the rays of the acutely bilobate heterocercal tail are preserved, the arrangement of which furnished the long desired clue to the position of the median row of scutes, proving that they were placed along the ventral margin of the body. Consequently it is now very improbable that the gridiron-like arrangement of ossicles in the anterior part of the body had anything to do with the support of the branchiæ."

Old Red Sandstone.—Further remains of plants were obtained from a new locality in the Lower Old Red Sandstone of Arran on the south side of Glen Rosic not far from the boundary fault. In going over the material obtained by him last season from the Lower Old Red Sandstone exposed in the railway cutting about a mile from Oban, MR. TAIT observed the casts of what appeared to be ostracods. Some specimens were sent to MR. JAMES W. KIRKBY, who confirmed this identification. The fossils were subsequently submitted to PROFESSOR RUPERT JONES who refers them to the genera *Aparchites*, *Isochilina*,

* *Summary of Progress for 1898*, p. 55.

† *Transactions of the Royal Society of Edinburgh*, vol. xxxix., pp. 827-864.

and *Beyrichia* (?), or *Drepanella*, one of the latter being (Mr. B. N. Peach.) curiously like the *Beyrichia* (?) *Holli*, Jones. Along with these casts occur the remains of *Cephalaspis* and *Pterygotus*. Although ostracods are plentiful in the Devonian Rocks of the South of England and the bivalve phyllopod *Estheria* is common in the Caithness flags, this is the first recorded instance of undoubted ostracods having been found in the Lower Old Red Sandstone of Scotland.

Carboniferous.—A further collection of Carboniferous fossils from the streamlet flowing into the Sliddery Water at Sliddery Water Head was made by MR. TAIT last season. The discovery has already been announced of *Carbonicola* (*Anthracosia*) *acuta*, together with fish remains in this section,* the general facies of the organisms indicating the horizon of the true Coal-measures. With these remains there were also discovered fragments of plants characteristic of the Lower Carboniferous subdivisions. The fossils collected this season help to define more precisely the boundary-line between the Upper and Lower Carboniferous rocks in this section. The evidence afforded by the various bands exposed in the Sliddery Water may be tabulated as follows in descending order.

4. Fine red mudstones, with numerous specimens of *Neuropteris heterophylla*, a characteristic Coal-measure form, and a specimen of *Spirinidium carbonicum* (Schimper), supposed at one time to be a plant, but now thought to be the egg capsule of a placoid fish, and known as *Palæoxyris carbonicus*. This form has hitherto been recorded from only one other locality in Scotland, Woodhead Quarry, near Kilmaurs, Ayrshire, in strata belonging to the lowest members of the Coal-measures.

3. Thin mussel-band ironstone (2-3 inches) charged with *Carbonicola* (*Anthracosia*) *acuta* and *C. (A.) robusta*.

2. Grey and red shale yielding the following fishes:—*Platysomus parvulus*, *Megalichthys Hibberti*, *Rhizodopsis sauroides*, *Strepsodus sauroides*, *Diplodus* sp. *Pleuroplus* sp. *Helodus* sp. together with the plants *Lepidodendron veltheimianum*, *Lepidostrobus*, *Stigmaria*, and *Calamites*.

1. Red tuff, containing chiefly calamites, the most abundant form being *Astrocalamites scrobiculatus*, a characteristic Lower Carboniferous form.

It thus appears that, the fossils of bed or zone 1 are characteristic of the Lower Carboniferous formations (i.e., Calciferous Sandstone and Carboniferous Limestone series); those of bed or zone 2 show a commingling of forms belonging partly to the Lower and partly to the Upper Carboniferous divisions, while those in beds or zones 3 and 4 are confined to the upper division (i.e., Millstone Grit and Coal-measures). It is evident, therefore, that bed or zone 2, represents palæontologically the passage-zone between the two great divisions of the Carboniferous system.

Rhætic.—The specimens obtained from these zones in Skye by MESSRS. MACCONOCHIE and TAIT, were forwarded to Jermyn Street, where they have been examined by MR. NEWTON and DR. KITCHIN as stated on p. 133.

The palæontological collections of the Survey of Scotland have

* *Summary of Progress for 1897*, p. 113.

(Mr. B. N.
Peach.)

been freely placed at the disposal of experts engaged in working out any of the groups of fossils there represented. These collections are, as far as possible, displayed to the public in the gallery assigned to the Survey in the Edinburgh Museum of Science; some of the specimens are necessarily still retained at the Survey Office for purposes of study and comparison. Among those who have made use of the Scottish specimens collected by the Survey, reference may be made to MISS DONALD, who has figured and described (*Quart. Journ. Geol. Soc.*, vol. lv., 1899), several specimens of Cambrian gasteropoda from the Durness limestone. These are :—

Ectomaria pagoda, var. *Peachi*. Plate xxi., figs. 1 and 2.
 „ „ var. *orientalis*. Plate xxi., figs. 3 and 4.
Hormotoma antiqua. Plate xxii., fig. 9.

DR. WHEELTON HIND has named for the Survey a large number of Lower Carboniferous lamellibranchs from Liddesdale, and has also figured and described in a Monograph of the British Carboniferous Lamellibranchiata (*Palaeontographical Society's Publications*, 1897), the following species :—

Myalina sublamellosa. Plate v., figs. 6, 7, 8.
Nuculana Sharmani. Plate xv., figs. 19–22.
 „ *stilla*. Plate xv., figs. 24, 25.

DR. TRAQUAIR, in addition to writing the important Memoir on the Silurian fishes belonging to the Geological Survey already referred to, has revised the nomenclature of the specimens of fossil fishes exhibited in the Museum. He also transferred on loan from the Natural History section to the Geological Survey cases several duplicate specimens of fossil fishes from the Caithness flagstones. These form a useful supplement to the specimens already in the Survey collection. DR. TRAQUAIR has also presented to the Survey a set of his figures of the new Silurian fishes, while MR. NEWTON has given copies of the plates that illustrate his Memoir on the Elgin Reptiles.

MR. KIDSTON has revised the nomenclature of the Carboniferous plants exhibited in the Survey collection in the Museum.

IV.—PRACTICAL APPLICATIONS OF THE WORK OF THE GEOLOGICAL SURVEY.

Applications for information on geological matters have, as usual, been numerous at the offices of the Survey in London, Edinburgh, and Dublin. From the London Office assistance has been afforded to the Local Government Board, the Colonial Office, and the Agent-General for New Zealand. Advice on various subjects connected with mining, well-sinking, soils, sites for houses, &c., has been given as far as possible, personally and by letter, to those who have sought for information.

It has been suggested by the Local Government Board that it would be much to the public advantage if arrangements could

be made whereby, on the request of the Board, officers of the Geological Survey should be sent to examine and report on any district where particulars might be required by that Department relating to water supply, the pollution of springs, sites for burial-grounds or sewage-farms, or other subjects where precise geological information is necessary. The matter is now before the Lords of the Committee of Council on Education, and it is hoped that the suggestion will be carried into effect.

At the Edinburgh Office of the Survey the number of applications by the public for information of a practical kind where geological knowledge is involved have been larger than in preceding years. They comprise enquiries relating to the position of coal-seams, limestones, ores, suitable building stones, &c., and also questions of water-supply, and the character of sub-soils. As an illustrative example reference may be made to enquiry by DR. AITKEN, Medical Officer of Health, Brighton, regarding the nature of the rocks and sub-soils of Edinburgh in connection with a Report on the comparative prevalence of diarrhœa on certain soils in several of the larger towns of the country. The desired information was prepared and furnished.

At the Dublin Office also, constant applications continue to be made in regard to geological information of an economic kind. Many of these have reference to mines and minerals, especially to coal and metalliferous ores. But in Ireland, as in the sister kingdoms, the most frequent subject of enquiry is that of water-supply. During the past year the reports in answer to these demands have sometimes been necessarily of a detailed character, and have involved the drawing of sections in explanation of the geological structure of the ground. Among the public departments that have availed themselves of Survey assistance in such matters were the War Department and the Congested Districts Board of Ireland.

V. MAPS, MEMOIRS, SECTIONS, &c., PUBLISHED DURING 1899.

A. — OFFICIAL.

I.—MAPS.

1.—*England and Wales.*

New Series of One-inch Maps.—Seven sheets of the New Series of one-inch maps have been published during last year, viz. :—

Sheet 155, Atherstone. Two editions with and without Drift. By C. FOX-STRONGAWAYS and W. W. WATTS (Charnwood).

Sheet 282, Devizes. One edition with Drift. By F. J. BENNETT and A. J. JUKES-BROWNE.

Sheet 315, Southampton. One edition with Drift. By W. WHITAKER and C. REID.

Sheet 325, Exeter. One edition with Drift. By W. A. E. USSHER.

Sheet 339, Newton Abbot. One edition with Drift. By H. B. WOODWARD, W. A. E. USSHER, and C. REID.

Sheet 340, Otterton. One edition with Drift. By W. A. E. USSHER.

Sheet 349, Ivybridge and Plymouth. One edition with Drift. By W. A. E. USSHER.

Old Series of One-inch Maps.—Sheet 19. Revised with Additions, by H. B. WOODWARD and A. STRAHAN.

The following One-inch New Series maps are in the hands of the engravers:—187, 203, 231, and 316.

Plans for printing these maps in colours are under consideration.

Six-inch Maps.—Northumberland. — Sheet 104, Whittonstall. By H. H. HOWELL.

Yorkshire.—Sheet 19, Hinderwell. By G. BARROW.

Six-inch Reference Maps.—96 MS. Coloured Copies of six-inch sheets and quarter-sheets have been made from the field-copies and deposited in the office for public reference. These are as follow:—

Brecknockshire.—31 S.E.; 32 S.W.; 37 N.E., S.E.; 38 N.W., S.W.
43 N.E., S.E.; 50 N.W.

Derbyshire.—57 N.E., S.E., N.W., S.W.; 58 N.E., S.E., N.W., S.W.; 60 N.W.

Devonshire.—105 N.E., S.E.; 106 N.E., N.W.

Dorset.—30 S.E.; 39 S.E.

Glamorganshire.—9, 11, 16, 41, 44, 45, 48, 49.

Hampshire.—48, 57, 64, 65, 66, 67, 73, 74, 75.

Leicestershire.—5 S.W.; 10 S.E., N.W., S.W.; 15 N.E., S.E., S.W.; 16 N.E., N.W., S.W.; 17 N.E., N.W.; 22 N.E.; 37 N.W.

Middlesex.—10 N.E., S.E.; 11 S.W., S.E.; 15 N.E., S.E., S.W.; 16 N.E., N.W., S.W.

Shropshire.—3 S.E., S.W.; 9 N.E., N.W.

Staffordshire.—8 S.W.; 10 S.E.; 11 N.E., S.E., N.W., S.W.; 12 N.E., N.W., S.W.; 13 S.W.; 16 N.E., S.E.; 17 N.E., S.E., N.W., S.W.; 18 N.E., S.E., N.W., S.W.; 22 N.E.,* S.E.,* N.W., S.W.*

Wiltshire.—67, 74, 75.

* Revised editions.

2.—Scotland.

Two sheets of the one-inch map of Scotland have been published during the past year, viz:—

46, embracing part of south-west Perthshire, extending from Loch Voil on the S.E. to Loch Tulla in the N.W., and the valleys of the Fillan, Dochart, and Lochay.

86, including parts of Aberdeenshire and Banffshire, extending from Grange east to Fyvie, and south to Huntly, and embracing a large part of the valley of the Deveron.

The following sheets of the one-inch map are in preparation.

27, containing the north part of Islay.

37, including the district on both sides of the upper part of Loch Fyne.

38, containing parts of Argyllshire, Dumbartonshire, Perthshire, and Stirlingshire.

55, showing part of Perthshire, including Blair Athole and Dalnaspidal.

15, new edition, embracing part of the Southern Uplands to the N.E. and S.W. of Sanquhar.

Manuscript copies of the following six-inch maps have been made and deposited in the office for public reference

Caithness, 11-17.

Skye, 38.

3.—*Ireland.*

It was found necessary to delay the issue of the revised editions of Sheets 37 and 38 until the igneous rocks had been re-examined as stated on p. 5. The revision has been completed, and these sheets are now published. Most of the other sheets of the Silurian districts which have been revised to the north of Dublin are now being prepared for engraving, and will be issued, it is expected, in the course of the present year.

The following duplicate copies of six-inch maps have been made, and are deposited in the office for reference by the public :—

County Antrim.—Parts of Sheets 4, 5, and 9.

„ Down.—Parts of Sheets 45, 46, 50, 51.

„ Mayo.—Sheets 82, 93, 114, and parts of Sheets 61, 65, 66, 67, 68, 74, 81, 92, 93, 105, 106, 115.

„ Tyrone.—Part of Sheet 15.

„ Wicklow.—Sheets 15, 22, and 29.

II.—MEMOIRS.

A. — OFFICIAL.

1.—*England and Wales.*

During the past year the following six Memoirs have been published :—

“Summary of Progress of the Geological Survey of the United Kingdom for 1898,” pp. vi., 216. Price 1s.

“The Geology of Belford, Holy Island, and the Farne Islands, Northumberland.” (Explanation of Quarter-sheet 110 S.E., Old Series; 4 New Series.) By WILLIAM GUNN, pp. iv., 155. Price .

“The Geology of the Country around Carlisle.” (Explanation of Sheet 107, Old Series; 16 and 17 New Series.) By T. V. HOLMES, pp. iv., 64. Price 1s. 3d.

“The Water-supply of Sussex from Underground Sources.” By W. WHITAKER and CLEMENT REID., pp. iv., 123. Price 3s.

“The Geology of the Country around Dorchester.” By CLEMENT REID., pp. iv., 52. Price 1s.

“The Geology of the South Wales Coal-field.” Part I., The country around Newport, Monmouthshire. By AUBREY STRAHAN, pp. vi., 97. Price 2s.

The following Memoirs are in different stages of progress :—

“The Cretaceous Rocks of Britain,” vol. i. The Gault and Upper Greensand of England. By A. J. JUKES-BROWNE. (*In the Press.*)

“The Geology of the Isle of Man.” By G. W. LAMPLUGH. (*Partly in type.*)

“The Geology of the country between Atherstone and Charnwood Forest.” By C. FOX-STRANGWAYS. (*Nearly ready for the printer.*)

“Guide to the Geology of London.” By W. WHITAKER. 6th edition. (*In preparation.*)

“The Geology of the country around Kingsbridge and Salcombe. By W. A. E. USSHER. (*Nearly ready for the printer.*)

“The Cretaceous Rocks of Britain,” vol. ii. Chalk of England. By A. J. JUKES-BROWNE. (*M.S. nearly ready for the printer.*)

- “The Geology of the country around Reading.” By J. H. BLAKE.
(*In preparation.*)
- “The Water Supply of Berkshire.” By J. H. BLAKE, with contributions
by W. WHITAKER. (*Nearly ready for printer.*)
- “The Geology of the South Wales Coal-field” :—
- Part 2. The country around Abergavenny. By A. STRAHAN,
J. R. DAKYNS and W. GIBSON. (*Nearly ready.*)
- Part 3. The country around Cardiff. By A. STRAHAN and
T. C. CANTRILL. (*In preparation.*)
- Part 4. The country around Pontypridd. By A. STRAHAN,
R. H. TIDDEMAN and W. GIBSON. (*In preparation.*)

2.—Scotland.

The large Memoir on the Silurian Rocks of Scotland referred to in previous *Annual Reports* was published last summer. It forms an octavo volume of 749 pages, with twenty-seven plates and 121 figures in the Text; also a coloured map and sections. It forms the first of the series of Stratigraphical Monographs, which has been entirely devoted to the geology of Scotland.

Another not less important contribution to the geology of the country is that on the North-West Highlands, to which allusion was made in the last *Annual Report*. As the literary work can only be undertaken during the season when field work has to be abandoned, the progress of so voluminous a Memoir as this must be necessarily slow. But so much of it has now been completed that the MS., it is confidently hoped, will be ready to be sent to the printer before the autumn of this year.

In connection with the preparation of the Memoir on the North-West Highlands it may be added that MR. ROBERT LUNN, of the Edinburgh Office, has, during the past season, visited the ground, and has taken fifty photographs of rock-sections and of escarpments of Torridon Sandstone, a selection from which will be used as illustrations of the Memoir. While in the north he also took thirty photographs of sections of Jurassic rocks in the district of Brora, Sutherlandshire, for the illustration of these rocks in a Survey Memoir.

No explanatory Memoir of Sheet 40 (Fife and Kinross) having hitherto been prepared, and no member of the staff being available for this duty, the Director-General undertook the work himself, and before the end of the year completed it. The MS. is only waiting for the completion of the Appendix of Fossils, and it will be sent to the printer as soon as that can be prepared. Another Memoir explanatory of Sheet 41 (Eastern Fife) will be taken in hand by the Director-General during the spring. Other Memoirs are in progress, including one on Cantyre by MESSRS. SYMES and HILL, and one on Islay by MR. WILKINSON.

III.—SECTIONS.

Three Sheets of Vertical Sections to further illustrate the South Wales Coalfield had been arranged during the early part of the year by MR. STRAHAN, and they were drawn to scale by MR. GILBERT WILLIAMS. Unfortunately, when the

work was almost completed by the lithographers, the building in which the stones and the original drawings were placed, was destroyed by fire, and no portion of the work was preserved. Steps have been taken to re-draw the sections and to issue them at as early a date as may be practicable.

B.—NON-OFFICIAL.

The following is a list of the non-official publications of the members of the staff during the year 1899:—

CLOUGH, C. T., and ALFRED HARKER.—“On a Coarsely Spherulitic (‘Variolitic’) Basalt in Skye.” *Trans. Edin. Geol. Soc.*, vol. vii., pp. 381-389.

CLOUGH, C. T., and DR. W. POLLARD.—“On Spinel and Forsterite from the Glenelg Limestone (Inverness-shire).” *Quart. Journ. Geol. Soc.*, vol. lv., pp. 372-380.

GEIKIE, SIR A.—Hutton’s “Theory of the Earth, with Proofs and Illustrations.” Vol. iii. Edited by SIR A. GEIKIE. 8vo, London.

GEIKIE, SIR A.—“Presidential Address. Section C., Geology, British Association. Dover, 1899.” *Rep. Brit. Assoc. for 1899 (1900)*, pp. 718-730.

GIBSON, W.—“Some Recent Work among the Upper Carboniferous Rocks of North Staffordshire and its Bearing on Concealed Coalfields.” *Rep. Brit. Assoc. for 1899 (1900)*, pp. 738, 739. *Geol. Mag.*, Dec. iv., vol. vi., pp. 505, 506.

GIBSON, W., and DR. WHEELTON HIND.—“On the Agglomerates and Tuffs in the Carboniferous Limestone Series of Congleton Edge.” With Appendix by H. H. ARNOLD-BEMROSE. *Quart. Journ. Geol. Soc.*, vol. lv., pp. 548-559.

GOODCHILD, J. G.—“The Bedshiel Kaims.” *Proc. Berwick Nats. Field Club*, pp. 295-312.

GOODCHILD, J. G.—“On the Genesis of some Scottish Minerals.” *Proc. Roy. Phys. Soc. Edin.*, vol. xiv., pp. 181-220.

GOODCHILD, J. G.—“Guide to the collection of Scottish Agates.” *Edin. Mus. Science and Art*, 1899.

GUNN, W.—“Notes on the rocks about Berwick-upon-Tweed.” *Proc. Berwick Nat. Field Club*, vol. xvi., p. 313.

HARKER, ALFRED.—“Chemical Notes on Lake District Rocks.” *Naturalist*, pp. 53-58, 149-154.

HARKER, ALFRED.—“Glaciated Valleys in the Cuillins, Skye.” *Geol. Mag.*, Dec. iv., vol. vi., pp. 196-199.

HARKER, ALFRED.—“On the Average Composition of British Igneous Rocks.” *Ibid.*, pp. 220-222.

HARKER, ALFRED.—“Notes on Subaerial Erosion in the Isle of Skye.” *Ibid.*, pp. 485-491.

HILL, J. B.—“On the Progressive Metamorphism of some Dalradian Sediments in the Region of Loch Awe.” *Quart. Journ. Geol. Soc.*, vol. lv., pp. 470-493.

HILL, J. B.—“The Lower Palaeozoic Rocks of the South of Scotland, viewed in connection with the Lower Palaeozoic Rocks of Cornwall.” *Trans. Roy. Geol. Soc., Cornwall*.

JUKES-BROWNE, A. J.—“The Submerged Platform of Western Europe.” *Geol. Mag.*, Dec. iv., vol. vi., pp. 94-96.

JUKES-BROWNE, A. J.—“Zones and ‘Chronological’ Maps.” *Ibid.* pp. 216-219.

JUKES-BROWNE, A. J.—“The Association of *Schlenbachia inflata* with *Hoplites interruptus*.” *Ibid.*, pp. 234, 235.

KYNASTON, H.—“Contributions to the Petrology of the Cheviot Hills.” *Trans. Edin. Geol. Soc.*, vol. vii., p. 390.

NEWTON, E. T.—“On Remains of *Amia* from Oligocene Strata in the Isle of Wight.” *Quart. Journ. Geol. Soc.*, vol. lv., pp. 1-10.

NEWTON, E. T.—“On a Megalosauroid Jaw from Rhaetic beds near Bridgend (Glamorganshire).” *Quart. Journ. Geol. Sc.*, vol. lv., pp 89–96.

NEWTON, E. T.—“Additional Notes on the Vertebrate Fauna of the Rock Fissure at Ightham (Kent).” *Ibid.*, pp. 419–429.

NEWTON, E. T.—“Remarks on *Mus Abbotti*.” *Proc. Zool. Soc.*, 1899 p. 318.

NEWTON, E. T.—“Note on the Mammalian Remains found at Carshalton.” *Trans. Croydon Micros. Nat. Hist. Club*, 1899, p. 292.

NEWTON, E. T.—“Report upon series of Bones obtained by Sir Thos. Wardle from a Cave at Red Hurst, near Wetton, Leek.” See Account of the researches at this Cave by Sir Thos. Wardle *The Leek Post*, Sat. Feb. 25th, 1899.

NEWTON, E. T.—“Notes on the Fossils collected by Colonel H. W. Feilden in Novaya Zemlya, 1897.” “Beyond Petsora Eastward,” by Henry J. Pearson, 8vo, London, 1899, p. 287 ; see also pp. 236, 242.

NEWTON, E. T.—“Notes on Fossils of Carboniferous Age, collected by Mr. Wm. S. Bruce, at Cape Cherni, Novaya Zemlya, in 1898.” “Beyond Petsora Eastwards,” p. 294.

NEWTON, E. T.—“On the Osteological specimens collected at Skitts Hill, near Braintree.” See paper on “A supposed Neolithic Settlement at Skitts Hill, near Braintree,” by Rev. J. W. Kenworthy, *Essex Naturalist*, vol. xi., p. 94.

PEACH, B. N.—“On some New Myriopods from the Palæozoic Rocks of Scotland.” *Proc. Roy. Phys. Soc. Edin.* vol. xiv., p. 113.

REID, C.—“The Origin of the British Flora.” 8vo, London, pp. vi, 191.

STRAHAN, A.—“The Age of the Vale of Clwyd.” *Geol. Mag.*, Dec. iv., vol. vi., pp. 111–117.

TEALL, J. J. H.—“The Natural History of Cordierite and its Associates. Presidential Address to Geologists' Association.” *Proc. Geol. Assoc.*, vol. xvi., pp. 61–74.

WEDD, C. B.—“Note on Barium Sulphate in the Bunter Sandstone of North Staffordshire.” *Rep. Brit. Assoc. for 1899 (1900)*, p. 740 ; *Geol. Mag.*, Dec. iv., vol. vi., p. 508.

WOODWARD, H. B., and W. A. E. USSHER.—“Excursion to Seaton, Sidmouth, Budleigh Salterton, and Exeter.” *Proc. Geol. Assoc.*, vol. xvi., pp 133–153.

APPENDIX.

CATALOGUE of TYPES and FIGURED SPECIMENS from the EOCENE and OLIGOCENE SERIES preserved in the Museum of Practical Geology.

By H. A. ALLEN, F.G.S.

N.B.—The letter T indicates that the specimen is the type of the species. The identity of some few specimens is not quite certain; these are marked [Doubtful].

EOCENE.

PLANTÆ.

- Alnites ? MacQuarrii**, Forbes. T.
E. Forbes, Quart. Journ. Geol. Soc., vol. vii., 1851, pl. iv., f. 3, p. 103.
Eocene. Ardtun, Mull.
- Andromeda reticulata**, Ett.
O. Heer, Phil. Trans., vol. 152, 1863, pl. lxviii., figs. 10, 11, p. 1067.
Bagshot Series. Bovey Tracey, Devon.
- Anona cycloperma**, Heer.
O. Heer, Phil. Trans., vol. 152, 1863, pl. lxx., f. 4, p. 1072.
Bagshot Series. Bovey Tracey.
- Anona ? devonica**, Heer. T.
O. Heer, Phil. Trans., vol. 152, 1863, pl. lxx., figs. 1, 2, 3, p. 1071.
Bagshot Series. Bovey Tracey.
- Apeiobopsis Symondsii**, De la Harpe. T.
De la Harpe, Mem. Geol. Survey, Isle of Wight, 1862, pl. vi., f. 5, p. 116.
Bagshot Series. Creech Barrow, Corfe Castle, Dorset.
- Aralia primigenia**, De la Harpe.
De la Harpe, Mem. Geol. Survey, Isle of Wight, 1862, pl. vii., f. 4, p. 117.
Lower Bagshot Series. Alum Bay, Isle of Wight.
- Aralia primigenia**, De la Harpe. T.
De la Harpe, Mem. Geol. Survey, Isle of Wight, 1862, pl. vii., f. 5, p. 117.
Lower Bagshot Series. Alum Bay.
- Buds.** T.
J. D. Hooker, Quart. Journ. Geol. Soc., vol. x., 1854, pl. iv., f. 25,
p. 163.
Reading Series. Reading.
- Cæsalpinia æmula**, Heer.
De la Harpe, Mem. Geol. Survey, Isle of Wight, 1862, pl. v., f. 6,
p. 118.
Lower Bagshot Series. Alum Bay.
- Cæsalpinia Bowerbanki**, De la Harpe. T.
De la Harpe, Mem. Geol. Survey, Isle of Wight, 1862, pl. v., f. 10,
p. 119.
Lower Bagshot Series. Alum Bay.

- Cæsalpinia ? brevis**, De la Harpe. T.
 De la Harpe, Mem. Geol. Survey, Isle of Wight, 1862, pl. v., figs. 12, 13,
 p. 119.
 Lower Bagshot Series. Alum Bay.
- Cæsalpinia ? mollis**, De la Harpe. T.
 De la Harpe, Mem. Geol. Survey, Isle of Wight, 1862, pl. v., f. 14,
 p. 119.
 Lower Bagshot Series. Alum Bay.
- Cæsalpinia Salteri**, De la Harpe. T.
 De la Harpe, Mem. Geol. Survey, Isle of Wight, 1862, pl. v., f. 11,
 p. 119.
 Lower Bagshot Series. Alum Bay.
- Carpolithes exaratus**, Heer. T.
 O. Heer, Phil. Trans., vol. 152, 1863, pl. lxx., figs. 24-27, p. 1079.
 Bagshot Series. Bovey Tracey.
- Carpolithes lividus**, Heer. T.
 O. Heer, Phil. Trans., vol. 152, 1863, pl. lxx., figs. 30 and 31, p. 1080.
 Bagshot Series. Bovey Tracey.
- Carpolithes vinaceus**, Heer. T.
 O. Heer, Phil. Trans., vol. 152., 1863, pl. lxx., f. 28, p. 1080.
 Bagshot Series. Bovey Tracey.
- Carpolithes Websteri** (Brongn.), Heer.
 O. Heer, Phil. Trans., vol. 152, 1863, pl. lxx., fig. 6, p. 1075.
 Bagshot Series. Bovey Tracey.
- Cassia Unger**i, Heer.
 De la Harpe, Mem. Geol. Survey, Isle of Wight, 1862, pl. v.,
 figs. 7, 8, 8a, p. 118.
 Lower Bagshot Series. Alum Bay.
- Cinnamomum lanceolatum**, Heer.
 O. Heer, Phil. Trans., vol. 152, 1863, pl. lxxvii., figs. 1, 2, 4 ; pl. lxxviii., f. 14
 p. 1063.
 Bagshot Series Bovey Tracey.
- Cinnamomum Rossmässleri**, Heer.
 O. Heer, Phil. Trans., vol. 152, 1863, pl. lxxvii., figs. 17, 18, p. 1062.
 Bagshot Series. Bovey Tracey.
- Cinnamomum Scheuchzeri**, Heer.
 O. Heer, Phil. Trans., vol. 152, 1863, pl. lxxvii., figs. 11, 14, 16, p. 1063
 Bagshot Series. Bovey Tracey.
- Cyperites deperditus**, Heer. T.
 O. Heer, Phil. Trans., vol. 152, 1863, pl. lx., f. 54, p. 1056.
 Bagshot Series. Bovey Tracey.
- Daphnogene Unger**i, Heer.
 O. Heer, Phil. Trans., vol. 152, 1863, pl. lxxv., figs. 1, 2, p. 1064.
 Bagshot Series. Bovey Tracey.
- Dalbergia ? Salteri**, De la Harpe. T.
 De la Harpe, Mem. Geol. Survey, Isle of Wight, 1862, pl. v., f. 9., p. 118.
 Lower Bagshot Series. Alum Bay.
- Dryandra acutiloba** (Brongn.)
 De la Harpe, Mem. Geol. Survey, Isle of Wight, 1862, pl. vii., figs. 6
 and 7, p. 115.
 Lower Bagshot Series. Alum Bay.

- Dryandra Bunburyi**, De la Harpe. T.
De la Harpe, Mem. Geol. Survey, Isle of Wight, 1862, pl. v., f. 4, p. 115.
Lower Bagshot Series. Alum Bay.
- Echitoneum cuspidatum**, Heer. T.
O. Heer, Phil. Trans., vol. 152, 1863, pl. lxiv., f. 5, p. 1068.
Bagshot Series. Bovey Tracey.
- Elæodendron ? Heeri**, De la Harpe. [Doubtful] T.
De la Harpe, Mem. Geol. Survey, Isle of Wight, 1862, pl. v., f. 5, p. 114.
Bagshot Series. Bournemouth.
- Equisetum Campbellii**, Forbes. T.
E. Forbes, Quart. Journ. Geol. Soc., vol. vii., 1851, pl. iii., figs. 6a, 6b,
p. 103.
Eocene. Ardtun, Mull
- Ficus Bowerbankii**, De la Harpe. T.
De la Harpe, Mem. Geo. Survey, Isle of Wight, 1862, pl. vi., figs. 1 and 2,
p. 112.
Lower Bagshot Series. Alum Bay.
- Ficus eucalyptoides**, Heer. T.
O. Heer, Phil. Trans., vol. 152, 1863, pl. lxv., figs. 3, 4, p. 1061.
Bagshot Series. Bovey Tracey.
- Ficus Falconeri**, Heer. T.
O. Heer, Phil. Trans., vol. 152, 1863, pl. lxiii., f. 1a ; pl. lxiv., fig. 7,
p. 1060.
Bagshot Series. Bovey Tracey.
- Ficus Forbesii**, De la Harpe. T.
De la Harpe, Mem. Geol. Survey, Isle of Wight, 1862, pl. vi., f. 4, p. 112.
Bagshot Series. Creech Barrow, Corfe Castle, Dorset.
- Ficus granadilla** (Massal.). T.
De la Harpe, Mem. Geol. Survey, Isle of Wight, 1862, pl. vi., f. 3, p. 113,
Lower Bagshot Series. Alum Bay.
- Ficus Pengellii**, Heer. T.
O. Heer, Phil. Trans., vol. 152, 1863, pl. lxv., f. 8, p. 1061.
Bagshot Series. Bovey Tracey.
- Filicites ? hebridicus**, Forbes. T.
E. Forbes, Quart. Journ. Geol. Soc., vol. vii., 1851, pl. ii., figs. 2a, 2b,
p. 103. Refigured as *Onoclea hebraidica*, J. S. Gardner, "Eocene
Flora," Mon. Pal. Soc., 1882, pl. xiii., figs. 5, 5a, p. 68.
Eocene. Ardtun, Mull.
- Gardenia Wetzleri**, Heer. T.
O. Heer, Phil. Trans., vol. 152, 1863, pl. lxix., f. 1, p. 1069.
Bagshot Series. Bovey Tracey.
- Goniopteris stiriaca**. *Vide Lastræa stiriaca*.
- Lastræa (Goniopteris) Bunburii**, Heer. T.
O. Heer, Phil. Trans., vol. 152, 1863, pl. lxiii., figs. 1 b, c, d, p. 1046.
Bagshot Series. Bovey Tracey.
- Lastræa (Goniopteris) stiriaca**, Heer. T.
O. Heer, Phil. Trans., vol. 152, 1863, pl. lvi., figs. 9, 10, 11, 14, 15, p. 1046.
Refigured as *Goniopteris stiriaca*, J. S. Gardner, Mon. Pal. Soc.,
1880, p. 40, f. 20 (Woodcut).
Bagshot Series. Bovey Tracey

Laurus Jovis, De la Harpe.**T.**

De la Harpe, Mem. Geol. Survey, Isle of Wight, 1862, pl. vii., f. 3, p. 114.
Lower Bagshot Series. Alum Bay.

Laurus primigenia, Unger.

O. Heer, Phil. Trans., vol. 152, 1863, pl. lxx., f. 6, p. 1062.

Bagshot Series.

Bovey Tracey.

Laurus ? Salteri, De la Harpe.**T.**

De la Harpe, Mem. Geol. Survey, Isle of Wight, 1862, pl. vii., f. 1, p. 115.
Lower Bagshot Series. Alum Bay.

Nymphæa Doris, Heer.**T.**

O. Heer, Phil. Trans., vol. 152, 1863, pl. lxx., figs. 32-37, p. 1072.

Bagshot Series.

Bovey Tracey.

Onoclea hebraidica. *Vide Filicites ? hebridicus*.**Palmacites Dæmonorops** (Unger).

O. Heer, Phil. Trans., vol. 152, 1863, pl. lv., figs. 8, 9, 10 ; pl. lxii., figs.
3, 6, 8, p. 1056.

Bagshot Series.

Bovey Tracey.

Pecopteris (Hemitelia ?) lignitum, Giebel.

O. Heer, Phil. Trans., vol. 152, 1863, pl. lvi., figs. 3, 5, 7, 8, 9, 10 ; pl.
lvii., f. 1, p. 1047.

Bagshot Series.

Bovey Tracey.

Platanites hebridicus, Forbes.**T.**

E. Forbes, Quart. Journ. Geol. Soc., vol. vii., 1851, pl. iv., f. 1, p. 103.
Eocene. Ardtun, Mull.

Platanites hebridicus, var. ? Forbes.**T.**

E. Forbes, Quart. Journ. Geol. Soc., vol. vii., 1851, pl. iii., f. 5, p. 103.
Eocene. Ardtun, Mull.

Pteris eocænica, Ett. and Gard.**T.**

Gardner and Ettingshausen, "Eocene Flora." Mon. Pal. Soc., 1882,
pl. xii., f. 11, 11a, pp. 32 and 62.

Bagshot Series.

Bournemouth.

Pterocarya denticulata ? Heer.

O. Heer, Phil. Trans., vol. 152, 1863, pl. lxx., fig. 5, p. 1074.

Bagshot Series.

Bovey Tracey.

Quercus eocenica, De la Harpe.**T.**

De la Harpe, Mem. Geol. Survey, Isle of Wight, 1862, pl. vii., f. 2,
p. 112.

Lower Bagshot Series.

Alum Bay.

Quercus Lyelli, Heer.

O. Heer, Phil. Trans., vol. 152, 1863, pl. lxiii., figs. 3, 5, 6, 7, 8 ; pl. lxviii.,
figs. 4, 6, p. 1058.

Bagshot Series.

Bovey Tracey

Rhamnites ? multinervatus, Forbes.**T.**

E. Forbes, Quart. Journ. Geol. Soc., vol. vii., 1851, pl. iii., f. 2, p. 103.
Eocene. Ardtun, Mull.

Rhamnites ? major, Forbes.**T.**

E. Forbes, Quart. Journ. Geol. Soc., vol. vii., 1851, pl. iii., f. 3, p. 103.
Eocene. Ardtun, Mull.

Sequoia Couttsiæ, Heer.

J. S. Gardner, Mon. Pal. Soc., 1883, pl. vi., figs. 14-17, pp. 36 and 90.

Middle Bagshot Series.

Bovey Tracey.

Sequoia Langsdorffii. *Vide Taxites ? Campbellii.***Taxites ? Campbellii,** Forbes.

T.

E. Forbes, Quart. Journ. Geol. Soc., vol. vii., 1851, pl. ii., figs. 1*a*, 1*b*
p. 103. Refigured as **Taxus Campbellii**, J. S. Gardner, "Eocene,
Flora," Mon. Pal. Soc., 1885, pl. x., figs. 1, 1*a*, p. 101.

Eocene.

Ardtun, Mull.

Taxus Campbellii. *Vide Taxites ? Campbellii.*

"Affinities doubtful."

E. Forbes, Quart. Journ. Geol. Soc., vol. vii., pl. iv., f. 2, p. 103.

Eocene.

Ardtun, Mull.

ANIMALIA.

PROTOZOA.

Nummulites elegans, J. C. Sow.

Rupert Jones, Quart. Journ. Geol. Soc., vol. xliii., 1887, pl. xi., f. 1,
p. 142.

Barton Series.

Whitecliff Bay, I.W.

ECHINODERMATA.

Astropecten ? Colei, Forbes.

T.

E. Forbes, Mon. Pal. Soc., 1852, pl. iv., figs. 3 *a*, *b*, p. 30.
London Clay.

Sheppey.

Astropecten crispatus, Forbes.

T.

Ansted, "Geology," vol. ii., 1844, p. 66 (Woodcut).
E. Forbes, Mem. Geol. Survey, vol. ii., part 2, 1848, p. 479.
E. Forbes, Mon. Pal. Soc., 1852, pl. iv., figs. 2 *a*, *b*, p. 29.

London Clay.

Sheppey.

Astropecten crispatus, Forbes.

E. Forbes, Mem. Geol. Survey, Decade I., 1849, pl. iii., figs. 3 *b*, *c*.
London Clay.

Sheppey.

Cainocrinus tintinnabulum, Forbes.

T.

E. Forbes, Mon. Pal. Soc. 1852, p. 33 (Woodcut).
London Clay.

Hornsey.

Cidaris websteriana, Forbes.

T

E. Forbes, Mon. Pal. Soc., 1852, pl. iii., f. 4, p. 22.
Barton Series.

Barton, Hants.

Cœlopleurus Wetherelli, Forbes

T.

E. Forbes, Mon. Pal. Soc., 1852, pl. iii., figs. 1 *a*, *b*, *c*, p. 24.
London Clay.

Sheppey.

Echinopsis Edwardsi, Forbes.

T.

E. Forbes, Mon. Pal. Soc., 1852, pl. iii., f. 2, p. 23.
Bracklesham Series.

Bracklesham.

Echinus dixonianus, Forbes.

T.

E. Forbes, Mon. Pal. Soc., 1852, pl. iii., f. 3, p. 22.
Barton Series.

Barton, Hants.

Eupatagus Hastingsiæ, Forbes.

T.

E. Forbes, Mon. Pal. Soc., 1852, pl. iii., f. 7, p. 26.
Barton Series.

Barton, Hants.

Goniaster (Astrogonium) marginatus, Forbes.

T.

E. Forbes, Mem. Geol. Survey, vol. ii., part 2, 1848, p. 475.
E. Forbes, Mem. Geol. Survey, Decade I., 1849, pl. 3, f. 2.
E. Forbes, Mon. Pal. Soc., 1852, pl. iv., f. 4, p. 31
London Clay.

Sheppey.

- Goniaster (Astrogonium) Stokesii**, Forbes. T.
 E. Forbes, Mem. Geol. Survey, vol. ii., part 2, 1848, p. 475.
 E. Forbes, Mem. Geol. Survey, Decade I., 1849, pl. 3, figs. 1 *a, c, d.*
 London Clay. Sheppey
- Goniaster tuberculatus**, Forbes. T.
 E. Forbes, Mon. Pal. Soc., 1852, pl. iv., f. 5, p. 31.
 London Clay. Sheppey
- Hemiaster Bowerbanki**, Forbes. T.
 E. Forbes, Mon. Pal. Soc., 1852, pl. iii., f. 6, p. 24.
 London Clay. Sheppey.
- Hemiaster branderianus**, Forbes. T.
 E. Forbes, Mon. Pal. Soc., 1852, pl. iii., figs. 8 *a, b, c*, p. 25.
 Barton Series. Barton, Hants.
- Hemiaster branderianus**, Forbes. T.
 E. Forbes, Mon. Pal. Soc., 1852, pl. iii., figs. 8 *d, e*, p. 25.
 London Clay. Haverstock Hill.
- Hemiaster ? Prestwichii**, Forbes. T.
 E. Forbes, Mon. Pal. Soc., 1852, pl. iii., figs. 5 *a, b, c*, p. 25.
 London Clay. Sheppey.
- Ophiura Wetherelli**, Forbes. T.
 E. Forbes, Mon. Pal. Soc., 1852, pl. iv., f. 7*b*, p. 32.
 London Clay. Highgate.
- Pentacrinus subbasaltiformis**, Miller. T.
 E. Forbes, Mon. Pal. Soc., 1852, pl. iv., figs. 9, 10, p. 34.
 London Clay. Hornsey.
- Spatangus Omalii**, Galeotti. T.
 E. Forbes, Mon. Pal. Soc., 1852, pl. iii., figs. 9 *a, c*, p. 28.
 Barton Series. Barton, Hants.

LAMELLIBRANCHIATA.

- Cytherea incurvata**, Edw. [Doubtful.]
 Lowry's Chart of the British Tertiary Fossils, 1866.
 Bracklesham Series.
- Modiola ? tubicola**, S. V. Wood. T.
 S. V. Wood, Mon. Pal. Soc., 1859, pl. xiii., f. 12, p. 73.
 London Clay. Whetstone ?
- Nucula proava**, S. V. Wood. T.
 S. V. Wood, Mon. Pal. Soc., 1862, pl. xx., figs. 3 *a, b*, p. 117.
 London Clay (Basement Bed). Near Bishopstone, Herne Bay.
- Nucula striatella**, S. V. Wood. T.
 S. V. Wood, Mon. Pal. Soc., 1862, pl. xx., fig. 9, p. 123.
 London Clay (Basement Bed). Herne Bay.
- Ostrea tabulata**, J. C. Sow. T.
 S. V. Wood, Mon. Pal. Soc., 1861, pl. iv. f. 1*b*, p. 31.
 Bracklesham ? Bognor.
- Perna croydonensis**, Newton. T.
 E. T. Newton, Proc. Geol. Assoc., vol. viii., 1883, p. 249.
 Woolwich and Reading Series. Park Hill, Croydon.

Vulsella deperdita ? Lam.

S. V. Wood, Mon. Pal. Soc., 1861, pl. ix., f. 2c, p. 35.
Barton Series.

Barton, Hants.

GASTEROPODA.

Camptoceras priscum, Austin.

T.

H. H. Godwin-Austen, Quart. Journ. Geol. Soc., vol. xxxviii., 1882,
pl. v., figs. 1-5, p. 220.
London Clay. Between East End Lane and Hensbrook, Sheppey.

Fusus nitidus, Price.

T.

F. G. H. Price, Proc. Geol. Assoc., vol. iii., 1874, pl. ii., fig. 2.
London Clay. Law Courts Area, Strand, London.

Pleurotoma varicosa, Price.

T.

F. G. H. Price, Proc. Geol. Assoc., vol. iii., 1874, pl. ii., fig. 1.
London Clay. Law Courts Area, Strand, London.

VERTEBRATA.

Arius crassus, (Koken) Newton.

T.

E. T. Newton, Proc. Zool. Soc., 1889, pl. xxi., figs. 1-3, p. 206.
Barton Series. Barton, Hants.

Notidanus serratissimus, Ag.

A. S. Woodward, Proc. Geol. Assoc., vol. xvi., 1899, pl. 1, f. 7, p. 6.
London Clay. Sheppey.

Emys delabechei, T. Bell.

T.

T. Bell in R. Owen, Mon. Pal. Soc., 1849, pl. xxviii., p. 74.
London Clay. Sheppey.

Agnopterus ? hantoniensis, Lyd.

T.

R. Lydekker, Cat. Foss. Birds in Brit. Museum, p. 97.
Middle Eocene. Hordwell.

Gastornis Klaasseni, Newton.

T.

E. T. Newton, Trans. Zool. Soc., vol. xii., 1886, pl. xxviii., xxix.,
p. 143.
Lower Eocene. Park Hill, Croydon.

Proherodius Oweni, Lyd.

T.

R. Lydekker, Cat. Foss. Birds in Brit. Museum, fig. 75, p. 364.
London Clay. Admiralty Building, St. James's Park.

Coryphodon croydonensis, Newton.

T.

E. T. Newton, Proc. Geol. Assoc., vol. viii., 1883, pl. iii., p. 250.
Lower Eocene. Park Hill, Croydon.

OLIGOCENE.

PLANTÆ

Andromeda reticulata, Ett.

O. Heer, Quart. Journ. Geol. Soc., vol. xviii., 1862, pl. xviii., f. 13,
p. 373.

Hamstead Series.

Hamstead, I.W.

Chara Lyellii (Forbes MS.), Salter.

T.

J. W. Salter in Forbes, Mem. Geol. Survey, Isle of Wight, 1856, pl. vii.,
f. 10, p. 160.

Bembridge Series.

St. Helens, I.W.

Chara tuberculata, Lyell, var. **Morrisii**, Salter.

T.

J. W. Salter in Forbes, Mem. Geol. Survey, Isle of Wight, 1856, pl. vii.,
f. 14, p. 159.

Hamstead Series.

Hamstead, I.W.

Cyperites Forbesii, Heer.

[Doubtful] T.

O. Heer, Quart. Journ. Geol. Soc., vol. xviii., 1862, pl. xviii., figs. 20, 21,
p. 373.

Hamstead Series.

Hamstead, I.W.

Limnocarpus headonensis (Gardner). Type of the genus.

T.

Clement Reid, Journ. Linn. Soc., vol. xxxiii., 1898, p. 465 (woodcut).

Lower Headon Series.

Hordle Cliff, Hampshire.

Nelumbium Buchii, Ett.

O. Heer, Quart. Journ. Geol. Soc., vol. xviii., 1862, pl. xviii., figs. 19
c, d, e, p. 374.

Hamstead Series.

Hamstead, I.W.

Sabal major, Unger.

J. S. Gardner, Rep. Brit. Assoc. for 1887, pl. v., f. 5, p. 423.

Bembridge Series.

Hamstead, I.W.

Sequoia Couttsiæ, Heer.

O. Heer, Quart. Journ. Geol. Soc., vol. xviii., 1862, pl. xviii., figs. 1-7,
p. 372. Refigured as **Athrotaxis Couttsiæ**, J. S. Gardner, "Eocene

Flora," Mon. Pal. Soc., 1884, pl. vi., fig. 3 and 8, pp. 36 and 90.

Hamstead Series.

Hamstead, I.W.

CÆLENERATA.

Madrepora anglica, Dunc.

T.

P. M. Duncan, Mon. Pal. Soc., 1866, pl. viii., figs. 1-7, p. 51.

Middle Headon Series

Brockenhurst.

Madrepora Roemeri, Dunc.

T.

P. M. Duncan, Mon. Pal. Soc., 1866, pl. viii., figs. 8, 10, 11, p. 51.

Middle Headon Series.

Brockenhurst.

Solenastræa cellulosa, Dunc.

T.

P. M. Duncan, Mon. Pal. Soc., 1866, pl. v., f. 7, p. 41.

Middle Headon Series.

Brockenhurst.

Solenastræa granulata, Dunc.

P. M. Duncan, Mon. Pal. Soc., 1866, pl. vi., f. 14, p. 45.

Middle Headon Series

Brockenhurst.

Solenastræa Koeneni, Dunc.

T.

P. M. Duncan, Mon. Pal. Soc., 1866, pl. v., figs. 8, 9, p. 42.

Middle Headon Series.

Brockenhurst.

BRYOZOA.

Membranipora Buski, Gregory.

T.

J. W. Gregory, Trans. Zool. Soc., vol. xiii., 1895, pl. xxix., f. 12, p. 229.
Headon Series. Colwell Bay, I.W.

LAMELLIBRANCHIATA.

Arca Websteri (Forbes MS.), Morris.

T.

J. Morris in E. Forbes, Mem. Geol. Survey, Isle of Wight, 1856, pl. iii.,
f. 8, p. 150.
Bembridge Series. Isle of Wight.

Corbula pisum, J. Sow.

J. Morris in E. Forbes, Mem. Geol. Survey, Isle of Wight, 1856, pl. i.,
f. 1, p. 145.
Hamstead Series (Upper Beds). Hamstead, I.W.

Corbula vectensis (Forbes MS.), Morris.

J. Morris in E. Forbes, Mem. Geol. Survey, Isle of Wight, 1856, pl. i.,
f. 2, pp. 46 and 145.
Hamstead Series (Upper Beds). Hamstead, I.W.

Cyclas Bristovii (Forbes MS.), Morris.

T.

J. Morris in E. Forbes, Mem. Geol. Survey, Isle of Wight, 1856, pl. ii.,
f. 3, p. 146.
Hamstead Series. Hamstead Cliff, I.W.

Cyrena deperdita, Lam.

J. Morris in E. Forbes, Mem. Geol. Survey, Isle of Wight, 1856, pl. vi.,
figs. 11, 11 *a*, *b*, p. 156.
Headon Series. Isle of Wight.

Cyrena gibbosula, Morris.

T.

J. Morris in E. Forbes, Mem. Geol. Survey, Isle of Wight, 1856, pl. vi.,
figs. 13, 13 *a*, *b*, p. 156.
S. V. Wood, Mon. Pal. Soc., Supp. 1877, pl. B, figs. 6 *a*, *b*, p. 14.
Headon Series. Colwell Bay.

Cyrena obtusa (Forbes MS.), Morris.

T.

J. Morris in E. Forbes, Mem. Geol. Survey, Isle of Wight, 1856, pl. iiii.,
figs. 4, 4 *a*, *b*, p. 149.
Bembridge Series. Hamstead Cliff, I.W.

Cyrena pulchra, J. C. Sow.

J. Morris in E. Forbes, Mem. Geol. Survey, Isle of Wight, 1856, pl. iii.,
f. 1, p. 148.
Bembridge Series (Green Marls). Isle of Wight.

Cyrena semistriata, Desh.

J. Morris in E. Forbes, Mem. Geol. Survey, Isle of Wight, 1856, pl. iii.,
f. 2, p. 148.
Bembridge Series. Isle of Wight.

Cyrena semistriata, Desh.

J. Morris in E. Forbes, Mem. Geol. Survey, Isle of Wight, 1856, pl. ii.,
f. 2, p. 146.
Hamstead Series (Corbula Beds). Hamstead, I.W.

Cyrena semistriata, Desh., var.

J. Morris in E. Forbes, Mem. Geol. Survey, Isle of Wight, 1856, pl. i.,
f. 3, p. 145.
Hamstead Series (Upper Beds). Hamstead, I.W.

- Cyrena transversa** (Forbes MS.), Morris. T.
 J. Morris in E. Forbes, Mem. Geol. Survey, Isle of Wight, 1856, pl. iii.
 f. 6, p. 149.
 Bembridge Series. Hamstead Cliff, I.W.
- Cyrena Wrightii** (Forbes MS.), Morris. T.
 J. Morris in E. Forbes, Mem. Geol. Survey, Isle of Wight, 1856, pl. iv.,
 figs. 11, 11 *a*, *b*, p. 153.
 Headon Series. Isle of Wight.
- Cytherea incrassata**, J. Sow.
 J. Morris in E. Forbes, Mem. Geol. Survey, Isle of Wight, 1856, pl. iv.,
 f. 10, p. 153.
 Headon Series. Colwell Bay.
- Cytherea incrassata** (cast of), J. Sow.
 J. Morris in E. Forbes, Mem. Geol. Survey, Isle of Wight, 1856, pl. iii.,
 f. 10, p. 150.
 Bembridge Series. Isle of Wight.
- Cytherea (Venus) Lyellii** (Forbes MS.), Morris. T.
 J. Morris in E. Forbes, Mem. Geol. Survey, Isle of Wight, 1856, pl. i.,
 f. 4, p. 145.
 Hamstead Series (Upper Beds). Hamstead, I.W..
- Modiola Prestwichii**, Morris. (*M. nystiana*, Forbes, on plate.) T.
 J. Morris in E. Forbes, Mem. Geol. Survey, Isle of Wight, 1856,
 pl. ii., f. 5, pp. 46 and 147.
 Hamstead Series. Hamstead Cliff, I.W.
- Mya (Panopæa) minor** (Forbes MS.), Morris, 1856. T.
 J. Morris in E. Forbes, Mem. Geol. Survey, Isle of Wight, 1856, pl. iii.,
 f. 3, p. 149.
 Bembridge Series. Isle of Wight.
- Mya (Panopæa) minor**, var. (Forbes MS.), Morris. T.
 J. Morris in E. Forbes, Mem. Geol. Survey, Isle of Wight, 1856, pl. ii.,
 f. 4, p. 146.
 Hamstead Series. Hamstead, I. W.
- Nucula headonensis** (Forbes MS.), Morris. T.
 J. Morris in E. Forbes, Mem. Geol. Survey, Isle of Wight, 1856, pl. vi.,
 figs. 12, 12 *a*, *b*, p. 156.
 Middle Headon Series. Colwell Bay.
- Nucula similis**, J. Sow.
 J. Morris in E. Forbes, Mem. Geol. Survey, Isle of Wight, 1856,
 pl. iii., f. 5, p. 149.
 Bembridge Marls. Isle of Wight.
- Ostrea callifera**, Lam.
 J. Morris in E. Forbes, Mem. Geol. Survey, Isle of Wight, 1856, pl. i.,
 figs. 5, 5*a*, p. 145.
 S. V. Wood, Mon. Pal. Soc., 1861, pl. v., f. 1*a*, p. 18.
 Hamstead Series (Upper Beds). Hamstead, I.W.
- Ostrea vectensis** (Forbes MS.), Morris. T.
 J. Morris in E. Forbes, Mem. Geol. Survey, Isle of Wight, 1856, pl. iii.,
 figs. 9, 9*a*, 9*b*, p. 150.
 S. V. Wood, Mon. Pal. Soc., 1861, pl. vii., figs. 5*a*, 5*b*, p. 32.
 Bembridge Series. Isle of Wight.
- Unio Austenii** (Forbes MS.), Morris. T.
 J. Morris in E. Forbes, Mem. Geol. Survey, Isle of Wight, 1856, pl. ii.
 f. 7, p. 147.
 S. V. Wood, Mon. Pal. Soc., 1864, pl. xx., f. 12, p. 133.
 Hamstead Series. Hamstead, I. W.

Unio Gibbsii (Forbes MS.), Morris.

S. V. Wood, Mon. Pal. Soc., 1864, pl. xx., f. 14, p. 133.

Hamstead Series.

Isle of Wight.

Unio Gibbsii (Forbes MS.), Morris.

[Doubtful]. T.

J. Morris in E. Forbes, Mem. Geol. Survey, Isle of Wight, 1856, pl. ii., f. 6, p. 147.

Hamstead Series.

Hamstead Cliff, I.W.

GASTEROPODA.

Ancillaria subulata, J. Sow.

J. Morris in E. Forbes, Mem. Geol. Survey, Isle of Wight, 1856, pl. vi., figs. 1, 1a, p. 155.

Headon Series.

Hordwell.

Borsonia sulcata (Edwards MS.), Morris.

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J. Morris in E. Forbes, Mem. Geol. Survey, Isle of Wight, 1856, pl. v., figs. 3, 3a, 3b, p. 154.

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Colwell Bay.

Cerithium Austeni, Morris.

T.

J. Morris in E. Forbes, Mem. Geol. Survey, Isle of Wight, 1856, pl. iii., f. 11, p. 150.

Bembridge Series.

Hamstead Point, I.W.

Cerithium concavum, J. Sow.

J. Morris in E. Forbes, Mem. Geol. Survey, Isle of Wight, 1856, pl. iv., f. 9, p. 153.

Headon Series.

Isle of Wight.

Cerithium elegans, Desh.

[Doubtful]

J. Morris in E. Forbes, Mem. Geol. Survey, Isle of Wight, 1856, pl. ii., f. 10, p. 147.

Bembridge Series.

Headon, I.W.

Cerithium inornatum, Morris.

T.

J. Morris in E. Forbes, Mem. Geol. Survey, Isle of Wight, 1856, pl. ii., f. 13, p. 148.

Hamstead Series.

Hamstead, I.W.

Cerithium margaritaceum, J. Sow. var. Morris.

J. Morris in E. Forbes, Mem. Geol. Survey, Isles of Wight, 1856, pl. iii., f. 13, p. 150.

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Hamstead, I.W.

Cerithium mutabile, Lam. var. ? Desh.

J. Morris in E. Forbes, Mem. Geol. Survey, Isle of Wight, 1856, pl. iii., f. 12, p. 150.

Bembridge Series.

Isle of Wight.

Cerithium mutabile, Lam. var. † Desh.

J. Morris in E. Forbes, Mem. Geol. Survey, Isle of Wight, 1856, pl. iv., f. 6, p. 152.

Headon Series.

Isle of Wight.

Cerithium plicatum, Brug.

J. Morris in E. Forbes, Mem. Geol. Survey, Isle of Wight, 1856, pl. i., f. 7, p. 146.

Hamstead Series (Upper Beds).

Hamstead, I.W.

Cerithium plicatum, Brug.

J. Morris in E. Forbes, Mem. Geol. Survey, Isle of Wight, 1856, pl. ii., f. 11, p. 147.

Hamstead Series (Upper Beds).

Hamstead, I.W.

- Cerithium pseudocinctum**, d'Orb. [Doubtful]
 Morris in Forbes, Mem. Geol. Survey, Isle of Wight, 1856, pl. iv., f. 7,
 p. 153.
 Headon Series. Colwell Bay.
- Cerithium Sedgwicki**, Morris. [Doubtful] T.
 J. Morris in E. Forbes, Mem. Geol. Survey, Isle of Wight, 1856, pl. ii.,
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- Cerithium trizonatum**, Morris. T.
 J. Morris in E. Forbes, Mem. Geol. Survey, Isle of Wight, 1856, pl. iv.,
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- Cerithium ventricosum**, J. Sow.
 J. Morris in E. Forbes, Mem. Geol. Survey, Isle of Wight, 1856, pl. iv.,
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- Fusus Edwardsii**, Morris. T.
 J. Morris in E. Forbes, Mem. Geol. Survey, Isle of Wight, 1856, pl. ii.,
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- Melania Forbesii**, Morris. T.
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- Melania inflata**, Morris. T.
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- Melania inflata**, Morris, var. *lævis*, Morris. T.
 J. Morris in E. Forbes, Mem. Geol. Survey, Isle of Wight, 1856,
 pl. ii., f. 9, p. 147.
 Hamstead Series. Hamstead Cliff, I.W.
- Melania muricata** (S. V. Wood MS.), Morris. T.
 J. Morris in E. Forbes, Mem. Geol. Survey, Isle of Wight, 1856, pl. iii.,
 f. 16, p. 151.
 Bembridge Series. Isle of Wight.
- Melania muricata**, Wood, var. *costata* (Sow. sp.), Morris.
 J. Morris in E. Forbes, Mem. Geol. Survey, Isle of Wight, 1856, pl. ii.,
 f. 14, p. 148.
 Hamstead Series. Hamstead, I.W.
- Melania muricata**, Wood, var. *excavata*, Morris. T.
 J. Morris in E. Forbes, Mem. Geol. Survey, Isle of Wight, 1856, pl. iii.,
 f. 17, p. 151.
 Bembridge Series. Bembridge, I.W.
- Melania per-acuminata** (Charlsw MS.), Morris. T.
 J. Morris in E. Forbes, Mem. Geol. Survey, Isle of Wight, 1856, pl. iv.,
 f. 5, p. 152.
 Headon. Isle of Wight.
- Melania turritissima**, Forbes. T.
 J. Morris in E. Forbes, Mem. Geol. Survey, Isle of Wight, 1856, pl. iii.,
 f. 14, p. 150.
 Probably the specimen figured in Lyell "Manual of Geology," 5th
 Edition, 1855, p. 209 (Woodcut).
 Bembridge Series. Hamstead Cliff, I.W.

Melanopsis brevis, J. C. Sow.

J. Morris in E. Forbes, Mem. Geol. Survey, Isle of Wight, 1856, pl. vi.,
f. 10, p. 156.

Headon Series.

Colwell Bay, I.W.

Melanopsis carinata, J. C. Sow.

J. Morris in E. Forbes, Mem. Geol. Survey, Isle of Wight, 1856, pl. vi.,
f. 8, p. 156.

Headon Series.

Headon Hill.

Melanopsis carinata, J. C. Sow.

J. Morris in E. Forbes, Mem. Geol. Survey, Isle of Wight, 1856, pl. vi.,
figs. 9, 9a, p. 156.

Headon Series.

Colwell Bay.

Melanopsis fusiformis, J. Sow.

J. Morris in E. Forbes, Mem. Geol. Survey, Isle of Wight, 1856, pl. vi.,
figs. 7, 7a, p. 156.

Headon Series.

Colwell Bay.

Melanopsis subcarinata, Morris.

T.

J. Morris in E. Forbes, Mem. Geol. Survey, Isle of Wight, 1856, pl. vi.,
f. 5, p. 156.

Headon Series.

Headon Hill.

Melanopsis subcarinata, Morris.

T.

J. Morris in E. Forbes, Mem. Geol. Survey, Isle of Wight, 1856, pl. vi.,
figs. 6 and 6a, p. 156.

Headon Series.

Headon Hill, I.W.

Melanopsis subfusiformis, Morris.

T.

J. Morris in E. Forbes, Mem. Geol. Survey, Isle of Wight, 1856, pl. vi.,
figs. 2, 2a, and 3, p. 155.

Headon Series.

Isle of Wight.

Melanopsis subulata, J. Sow.

[Doubtful]

J. Morris in E. Forbes, Mem. Geol. Survey, Isle of Wight, 1856, pl. vi.,
figs. 4 and 4a, p. 155.

Headon Series.

Headon Hill.

Natica labellata, Lam.

J. Morris in E. Forbes, Mem. Geol. Survey, Isle of Wight, 1856, pl. i.,
f. 6, p. 146.

Hamstead Series (Upper Beds).

Hamstead, I.W.

Pleurotoma headonensis (Edw. MS.), Morris.

T.

J. Morris in E. Forbes, Mem. Geol. Survey, Isle of Wight, 1856, pl. v.,
f. 4, p. 155.

Headon Series.

Colwell Bay.

Pleurotoma innexa (Sol.).

J. Morris in E. Forbes, Mem. Geol. Survey, Isle of Wight, 1856, pl. v.,
f. 5, p. 154.

Headon Series.

Colwell Bay.

Pleurotoma plebeia, J. C. Sow.

J. Morris in E. Forbes, Mem. Geol. Survey, Isle of Wight, 1856, pl. v.,
figs. 1, 1 a, b, p. 154.

Headon Series.

Colwell Bay.

Pleurotoma plebeia, var. Morris (var. b Forbes MS.), Morris.

T.

J. Morris in E. Forbes, Mem. Geol. Survey, Isle of Wight, 1856, pl. v.,
f. 2, p. 154.

Middle Headon Series.

Isle of Wight.

Rissoa (Hydrobia) Chastelii ? (Nyst) (*Hydrobia* on plate.)

J. Morris in E. Forbes, Mem. Geol. Survey, Isle of Wight, 1856, pl. iv.,
f. 3, pp. 148 and 152.

Headon Series.

Isle of Wight.

Scalaria lævis, Morris.

T.

J. Morris in E. Forbes, Mem. Geol. Survey, Isle of Wight, 1856, pl. iv.,
f. 1, p. 151.

Headon Series.

Isle of Wight.

VERTEBRATA.

Amia anglica, Newton.

T.

E. T. Newton, Quart. Journ. Geol. Soc., vol. lv., 1899, pl. i.,
figs. 1-5, p. 1.

Bembridge Marl.

Hamstead, I.W.

Amia anglica, Newton.

E. T. Newton, Quart. Journ. Geol. Soc., vol. lv., 1899, pl. i., fig. 19, p. 1.
Osborne Beds.

Ryde House, Ryde, I.W.

Amia Colenutti, Newton.

T.

E. T. Newton, Quart. Journ. Geol. Soc., vol. lv., 1899, pl. i., fig. 22, p. 8.
Osborne Beds.

King's Quay, I.W.

Hyopotamus sp.

W. Kowalevsky, Phil. Trans., vol. 163, 1873, pl. xxxix., fig. 7, p. 30.
Hamstead Series.

Hamstead, I.W.

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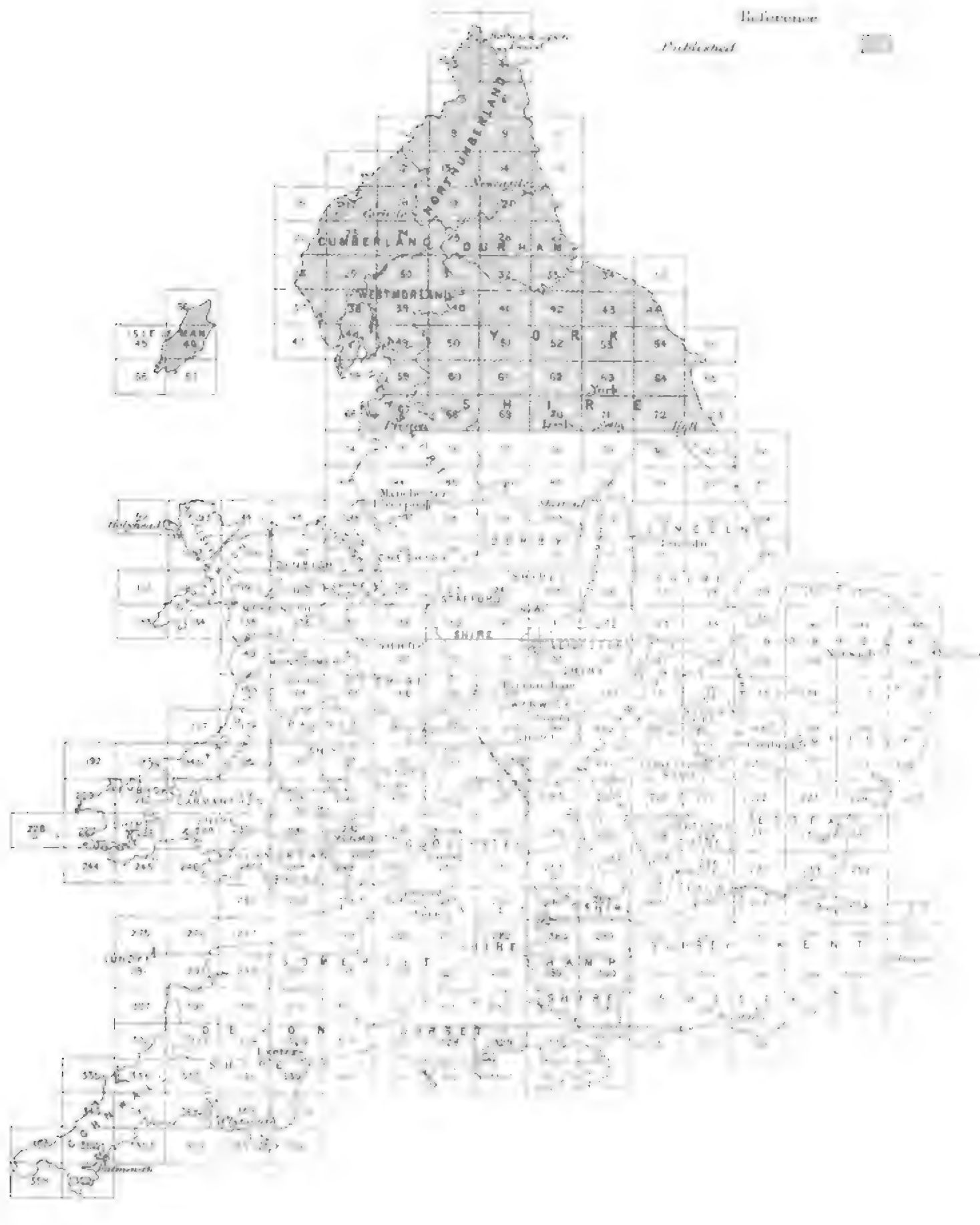


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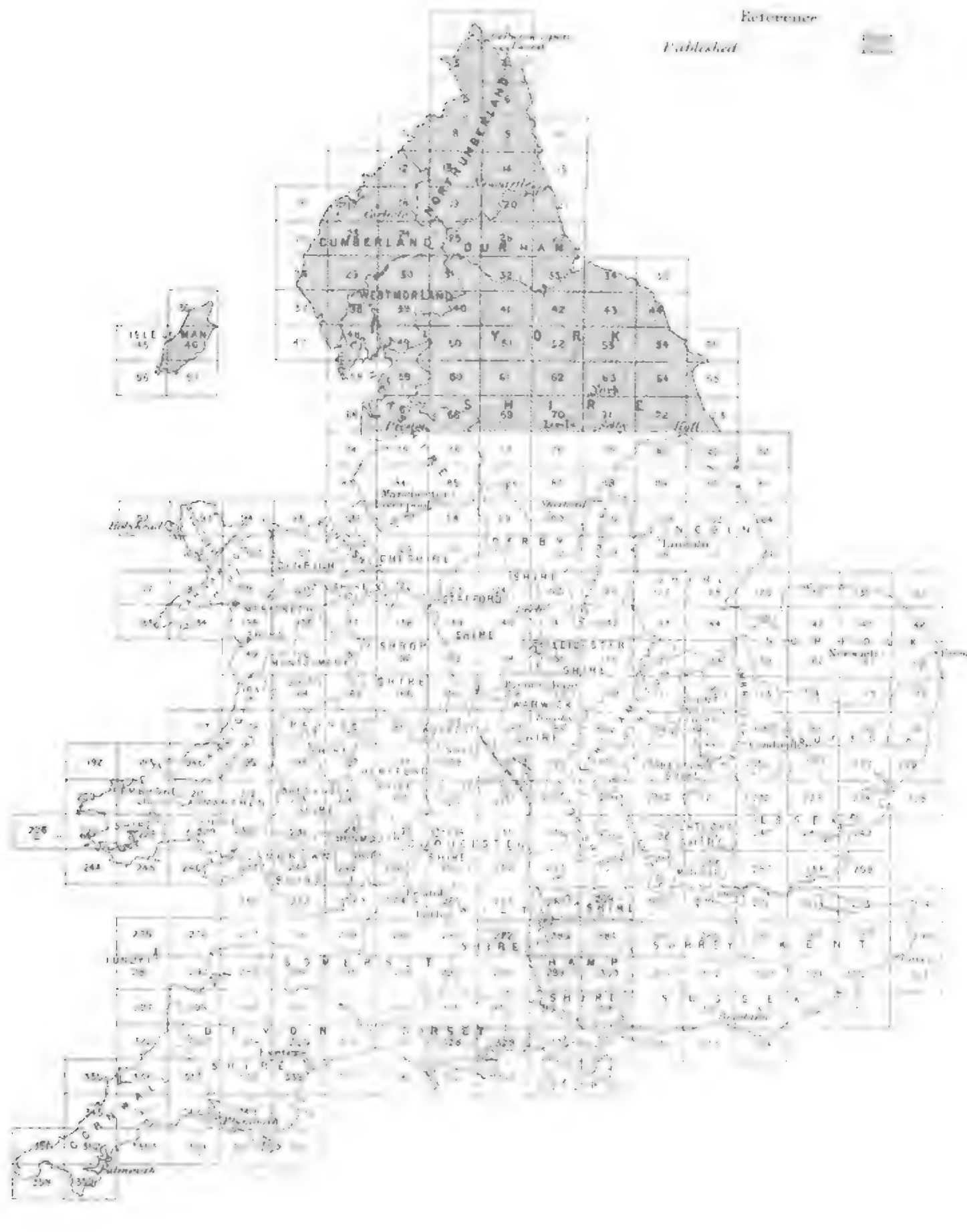


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PREFACE.

THE present volume has been prepared for the purpose of making known the general plan of work and the state of progress of the Geological Survey of the United Kingdom during the year 1900. The nature and some of the more interesting or important features of the various lines of investigation in the field, the office, the laboratory, and the museum, are briefly described. As far as possible, the account of the work of each member of the staff is given as reported by himself. In such narratives, even where the Editor exercises to the full his functions of excision and condensation, it is difficult to avoid what may seem to be a superfluity of local detail. It must be remembered, however, that the great value of much of the work consists in this very detail, which, even where it may have little interest for the general reader, is appreciated by those to whom new observations in districts known to them are welcome.

The general distribution of the mapping in each of the three kingdoms is in the following pages first briefly sketched. Thereafter the additions made by the staff last year to our knowledge of each of the geological formations in the country are given in stratigraphical order, from the oldest gneiss up to the most recent deposits. The most remarkable of these additions is undoubtedly the discovery of a large volcanic vent in the Isle of Arran, in which have been preserved masses of Rhætic, Liassic, and Upper Cretaceous strata. It is thus possible to determine beyond reasonable doubt that the later igneous rocks of that island are of Tertiary age, to show that Mesozoic formations once stretched into the basin of the Clyde, and to demonstrate how stupendous has been the denudation of the general surface of the country since the Cretaceous period.

Another important and suggestive observation is the relation discovered to exist between some younger granites of the Southern Highlands and the vents of the Lorne volcanic region. As these vents belong to the time of the Lower Old Red Sandstone, the granites which invade them cannot be older than that time, but probably belong to the remarkable series of granite extrusions which in the British Islands intervened between the close of the Upper Silurian and the beginning of the Upper Old Red Sandstone periods.

The Petrographical work of the Survey is then briefly described, and a summary is thereafter given of an investigation of the remarkable assemblage of eruptive rocks which has been detected in Assynt, and of the metamorphism induced by them on the surrounding dolomites.

The Palæontological observations made at the Museum of Practical Geology, and at the Survey Office in Edinburgh, are next shortly epitomised, and attention is called to a few of their more important features. Brief allusion is likewise made to the continued applications received at the several offices of the Survey from the general public and from Government departments and Local Boards for advice and assistance in matters where a knowledge of geology, and more especially of the geological structure of particular districts, is involved.

A list is given of the maps, sections, memoirs, and other publications issued by the Geological Survey during the past year, and now in course of preparation, together with a statement of the non-official contributions to science made by members of the staff.

In the Appendices will be found catalogues of types and figured specimens from British Pliocene and Pleistocene, and Devonian strata in the Jermyn Street Museum. These are the second and third instalments of the series of such catalogues, which, as announced in the last *Summary of Progress*, it is intended to prepare and publish.

As I retire to-day from the Public Service in which I have spent upwards of forty-five years, I may be allowed, as my

closing official act, to express the satisfaction with which I hand over the administration of the Geological Survey and Museum to my friend and colleague MR. J. J. H. TEALL, and the confidence with which I look forward to the increased strength and efficiency of the institution.

ARCH. GEIKIE,
Director-General.

*Geological Survey Office,
28, Jermyn Street, London,
February 28th, 1901.*

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SUMMARY OF PROGRESS

OF THE

GEOLOGICAL SURVEY

FOR 1900.

PART I.—FIELD-WORK.

I.—GENERAL DISTRIBUTION AND STATISTICS OF THE STAFF.

1.—ENGLAND AND WALES.

In continuation of the arrangement made in the summer of 1899, the immediate charge of the Staff of the Survey in England and Wales has been in the hands of MR. H. B. WOODWARD, F.R.S. He has been chiefly engaged at the head office, but has from time to time visited the officers in the field. The pressure of other duties has for some years past made it impossible for him to resume the mapping of the Jurassic rocks of the north-west Highlands, in which he had made some progress. As it was necessary to complete this work in order to allow of the publication of the maps, and as none of the Staff in Scotland possesses the requisite acquaintance with the Jurassic formations to be able to continue MR. WOODWARD'S mapping, it was deemed best that MR. C. B. WEDD should be detailed for the purpose from his district in Staffordshire, and that Mr. WOODWARD should start him on the Jurassic ground in Skye—an arrangement which has proved entirely satisfactory.

As stated in previous *Summaries of Progress*, the field-work of the Survey in England and Wales now consists in the revision of the published maps, and in the resurvey of the Coal-fields and of those counties where the Drifts were not originally mapped. The general distribution of the Staff has remained nearly the same as described in the last *Summary*. During the summer, however, it was found necessary temporarily to transfer three members of the English Staff to complete or expedite the

field-work in Scotland. MR. S. B. WILKINSON, who is now stationed in Cornwall, was for this reason engaged for part of the season in finishing his mapping of the Island of Jura; MR. J. B. HILL, also stationed in Cornwall, was likewise employed in pushing forward the Survey of Argyllshire in continuation of his previous work in that county, while MR. WEDD undertook, during two of the summer months, the Jurassic mapping above referred to. These interchanges for the advancement of the field-work in Scotland are further referred to on pp. 4 to 6. The withdrawal of these officers for part of the year has necessarily helped to reduce the area surveyed in England and Wales.

In the district of Berkshire, Buckinghamshire, and Oxfordshire, Mr. J. H. BLAKE, from his station at Oxford, has surveyed a tract of 25 square miles, including 101 miles of boundary-lines, of which 79 relate to superficial deposits.

In Cambridgeshire and Huntingdonshire, MR. WEDD, who was detailed for this special purpose, surveyed the Corallian rocks in order to complete a map, and traced there $34\frac{1}{2}$ miles of new boundary-lines in these formations.

The revision and resurvey in the region embracing Cheshire, Derbyshire, Leicestershire, Shropshire, and Staffordshire have been, as hitherto, supervised by MR. FOX STRANGWAYS, with whom have been associated MR. GEORGE BARROW, MR. WALCOT GIBSON, MR. T. I. POCKOCK, and MR. WEDD. An area of $140\frac{1}{2}$ square miles has there been surveyed, including $970\frac{1}{2}$ miles of boundary-lines, whereof 533 belong to the Drifts. For reasons which will be more fully stated further on, MR. BARROW was able to give only a short time in the early summer to field-work in the Staffordshire district when he mapped a tract of $4\frac{1}{2}$ square miles and traced 10 miles of boundary among the solid rocks. Besides mapping upwards of 60 square miles of this district, MR. GIBSON and MR. WEDD had to spend a considerable amount of time in the laborious duty of examining mining plans and sections in the colliery offices of North Staffordshire. MR. GIBSON has now gained an acquaintance with the details of these Midland coal-pits, which is of great practical value in regard to questions that arise as to the extension and identification of the several subdivisions of the Coal-measures under the New Red Sandstone of that part of England. To the east and south-east of Macclesfield a tract of ground, nearly 30 square miles in area, of much practical importance, but considerably complicated by faults and folds, and requiring a good deal of time for its examination, has been mapped by MR. POCKOCK. In addition to the general supervision of the field-work of his colleagues, MR. FOX STRANGWAYS has himself mapped a tract of 45 square miles, which embraces 324 miles of boundary-lines, whereof 44 are those of the solid rocks and 280 those of the superficial formations. He has completed the survey of Sheet 156, and has written a memoir for the adjacent Sheet 155, which has been published.

In Cornwall and Devonshire the field-work has proceeded along

the same lines as in the last few years. MR. USSHER mapped 22½ square miles, including 140 miles of geological boundaries. His time, however, has been partly taken up in the preparation of a memoir on a part of Devonshire surveyed by him, as well as of other memoirs, now in progress, relating to the new series of maps, and partly in tracing fresh boundary-lines in areas already surveyed. MR. WILKINSON has completed an area of 43½ square miles in the south-west of Cornwall, including 110 miles of boundary; but, as already stated, he was transferred for a portion of the year to complete work in Scotland. MR. HILL's return of field-work in Cornwall amounts to 30 square miles, surveyed from his station at Falmouth, and includes 156 miles of geological boundary. But he also, as already stated, spent a considerable part of the working season in completing the mapping of some of the ground in Argyllshire on which he was formerly engaged.

In Dorset and Wiltshire the field-work has been carried on under the superintendence of MR. CLEMENT REID, with whom MR. E. E. L. DIXON has been associated. The area surveyed in these counties amounts to 39½ square miles, and includes 252 miles of boundary-lines, of which 73 belong to the drift deposits. Besides his duties in the field, MR. REID has taken charge of the work of this office during MR. WOODWARD's absence, and his assistance has been of much service in preparing memoirs for the printer, in answering public inquiries, and above all, in the elaboration of a scheme for the production of maps by colour-printing, to which reference will be made further on. It should be mentioned that the area examined by MR. DIXON was considerably larger than that which appears in the returns as surveyed by him, inasmuch as he had to trace fresh boundary-lines required in the ground formerly mapped by MR. JUKES BROWNE.

In the revision of the geology of Sussex, MR. G. W. LAMPLUGH has surveyed an area of 42½ square miles, including 203 miles of boundary, of which 50 belong to the superficial deposits. But in addition to this mapping, his time and attention have been required to gather the geological results that might be obtainable from the sinking for coal now being carried on at Dover, while he has also necessarily been much occupied in correcting the proofs of his Memoir on the Geology of the Isle of Man.

In South Wales the re-survey of the coal-field has been continued under the superintendence of MR. A. STRAHAN, with the assistance of MR. R. H. TIDDEMAN and MR. T. C. CANTRILL. The area surveyed by these officers during last year amounts to 90½ square miles, with 609 miles of boundary-lines, whereof 292 or nearly half have reference to the various superficial deposits. In connection with the field-work in this region, DR. W. POLLARD spent a short time in the peninsula of Gower resuming and continuing his investigation of the dolomitisation of the Carboniferous Limestone.

The total area of ground surveyed during the past year in

England and Wales amounts to 434 square miles, and the length of boundary-lines traced is 2,575 miles, of which 1,079 belonged to the superficial deposits. This considerable diminution of area has arisen from several causes, of which the chief has been the necessity of overtaking the accumulation of indoor work which had to be pushed forward in order to permit the completion of certain maps and memoirs. A large part of this work has been cleared off, and it is anticipated that the mapping will now proceed at a quicker pace.

It will be observed that while there has been a falling off in the total area surveyed, the field-work has at the same time increased in complexity, for every square mile mapped has necessitated the tracing of six miles of boundary-lines.

2.—SCOTLAND.

The provisional arrangement referred to in the last *Summary of Progress*, by which the immediate supervision of the Survey of Scotland was placed in the hands of MR. JOHN HORNE, F.R.S., has been continued. MR. HORNE has not only undertaken the general charge of the Scottish branch of the establishment, but, during a part of the year, has resumed his field-work in Inverness-shire, with the view of clearing off some of the outlying portions of the ground already surveyed by him.

The only changes in the staff in Scotland are the appointment of MR. CECIL B. CRAMPTON, M.B., C.M., as an Assistant Geologist, who entered on his duties in April last, and the promotion of MR. L. W. HINXMAN, B.A., to be "Acting Geologist" until the re-organisation of the service has been completed and he can be placed on the permanent list.

The amount of field-work returned for the past year has fallen somewhat below the average, owing partly to MR. BARROW'S serious ill-health, which necessitated his retirement from the field after a period of only three weeks; partly to delays unavoidably arising in the completion of the mapping of the Island of Arran, which, though the area still to be surveyed amounted only to $6\frac{1}{4}$ square miles, involved the re-examination of certain complicated tracts consequent upon important recent discoveries; and partly to MR. GUNN'S earlier return to the office for the purpose of finishing the dry proof of Sheet 21 by the end of December.

In Aberdeenshire, which embraces a small part of the area surveyed by MR. HINXMAN, one quarter of a square mile and $26\frac{3}{4}$ miles of boundary are reported by him; and in the same county MR. CUNNINGHAM CRAIG mapped $26\frac{3}{4}$ square miles with $205\frac{1}{2}$ miles of boundary.

In Argyllshire, the survey of the Island of Jura was completed, of which $6\frac{1}{2}$ square miles with 51 miles of boundary were mapped by MR. PEACH; and $6\frac{1}{2}$ square miles with 59 miles of

boundary by MR. WILKINSON. From Oban as a centre, MR. SYMES surveyed $31\frac{1}{2}$ square miles, and traced 190 miles of boundary. In the same county, MR. WILSON mapped $17\frac{1}{2}$ square miles with 61 miles of boundary; MR. HILL, 10 square miles with 124 miles of boundary; and MR. KYNASTON, 53 square miles with 273 miles of boundary.

In the county of Banff, MR. CUNNINGHAM CRAIG surveyed 4 square miles with $5\frac{1}{2}$ miles of boundary.

In the Island of Arran, MR. GUNN mapped $6\frac{1}{4}$ square miles, and traced 111 miles of boundary.

In the county of Caithness, from Wick as a centre, MR. PEACH surveyed 41 square miles with 101 miles of boundary, and DR. CRAMPTON $44\frac{1}{2}$ square miles with 38 miles of boundary and $6\frac{1}{2}$ miles of coast line.

In Dumbartonshire, MR. CUNNINGHAM CRAIG traced 21 miles of boundary in ground previously surveyed.

In the county of Inverness, between Strath Nairn and the valley of the Findhorn at Tomatin, MR. HORNE surveyed 21 square miles with 94 miles of boundary. In the west part of the same county, south of Loch Hourn, MR. CLOUGH completed an area of $24\frac{1}{2}$ square miles with 224 miles of boundary. In the central and eastern parts of the county, MR. HINXMAN mapped $28\frac{1}{4}$ square miles with $119\frac{1}{2}$ miles of boundary; and in the Fort William District, MR. GRANT WILSON surveyed 18 square miles with 88 miles of boundary. In the island of Skye, MR. HARKER mapped $13\frac{3}{8}$ square miles with 216 miles of boundary, and MR. WEDD 6 square miles with $37\frac{5}{8}$ miles of boundary.

In Perthshire, MR. BARROW, before he was prostrated by illness, mapped 3 square miles with 20 miles of boundary; MR. GRANT WILSON surveyed 22 square miles with 74 miles of boundary, while MR. CUNNINGHAM CRAIG traced 135 miles of new boundary on ground previously surveyed.

In Ross-shire, MR. PEACH surveyed 12 square miles with 76 miles of boundary; MR. CLOUGH, $7\frac{1}{8}$ square miles with 99 miles of boundary; and MR. HINXMAN, 27 square miles with 168 miles of boundary.

The total area surveyed in Scotland during the year has been $430\frac{5}{8}$ square miles, and the total length of boundary-lines traced amounts to $2,618\frac{1}{4}$ miles.

The Director-General paid a series of visits of inspection of the field-work in Scotland. In Strath Nairn he had an opportunity of seeing some of the exceedingly interesting recent work of MR. HORNE in that district. Thence he went on to Skye, and saw a portion of MR. HARKER's mapping in the Island of Scalpay. On the southward journey he took occasion to halt in the Perthshire Highlands, where in company with the District Surveyor MR. PEACH, and MR. GRANT WILSON, he inspected a part of the ground round Shiehallion, where some additional lines are needed; and also visited, with MR. CUNNINGHAM CRAIG, a portion of the area between the valleys of the Tay and the Tummel, on which that officer has recently been engaged. Before returning to headquarters he spent a week in Arran and

saw with MR. GUNN the evidence of some of the remarkable discoveries which MR. PEACH, MR. GUNN, and MR. MACCONOCHIE have recently made in the island.

3.—IRELAND.

The field-work has been continued along the same lines as during the last few years. MR. NOLAN, owing to a rheumatic affection which incapacitated him from hill climbing, was prevented last year from continuing his revision of the Drift on which he has been engaged for several years.

MR. EGAN and MR. MCHENRY completed their revision of the Silurian rocks of Wicklow and Wexford. The former of these two geologists found himself early in September unequal to the fatigues of field-work, and had to return to the office. Having suffered serious injury from a car-accident, in which the Director-General and MR. MCHENRY were also involved, he had never thereafter regained his health and strength. He struggled with his weakness during the early half of last summer in the field, but was then compelled to take to indoor employment. Internal complications traceable to jaundice, arising from the effects of the accident, eventually assumed a malignant form, and finally carried him off on the 6th January. His gentle disposition made him everywhere a favourite, and his long and assiduous service to the Survey deserves hearty recognition.

MR. MCHENRY pushed the revision work in County Wexford until he joined up lines with MR. KILROE. Later in the year he was engaged with MR. SEYMOUR in a revision of the Silurian and igneous rocks to the north and to the south of Dublin, and of the numerous dykes along the southern coast of County Down.

MR. KILROE completed the revision of 216 miles of Silurian ground in the counties of Kilkenny, Wexford, and Waterford.

MR. SEYMOUR has studied and reported on 228 rock-slides, and has had 119 new slices prepared and added to the Irish collection, which now numbers 2,470. Besides these specimens he has examined and named a series of eighty slices which already existed in the collection but had not been determined. Of the rock-slides studied and reported on by him 115 were sent to him from Scotland, as it was impossible to find time for their study in the Petrographical Department at Jermyn Street. MR. SEYMOUR likewise at various times went to the field for the purpose of assisting the surveyors in the determination of the petrographical character of the rocks, and of gaining useful information for himself in regard to the relations of the masses in the field.

MR. CLARK, the fossil-collector, was occupied in the counties of Meath, Dublin, Wicklow, Kildare, Wexford, and Waterford, from which he obtained a large series of fossils and of rock specimens for the illustration of the new edition of the maps and the improvement of the Survey collections in the Museum of Science and Art in Dublin.

During a tour of inspection in Ireland the Director-General took occasion to visit some critical sections in the counties of Wicklow and Wexford with MESSRS. EGAN, MCHENRY, and SEYMOUR, and arranged as to the way in which the rocks were to be mapped. He likewise spent some days in the county of Waterford with MR. KILROE and MR. SEYMOUR, giving attention more particularly to the coast-sections and deciding on the principle to be followed in the final mapping of that complicated region.

The chief scientific and economic results of the field-work of the Survey in the three kingdoms will now be given in stratigraphical order, beginning with the oldest geological formations.

Pre-Cambrian.

ROSS-SHIRE.

From Aultguish, between Garve and Ullapool, MR. B. N. PEACH continued the mapping done by him in former years. Mr. B. N. Peach. The prevalent rocks which he examined in this district belong to the type of "Moine schists" or "quartzose flagstones." They are essentially granulitic quartz-schists, with varying quantities of felspar, muscovite and biotite. Muscovite-biotite-gneiss, a more or less matted aggregate of biotite and muscovite, with granulitic quartz and felspar, and in places granitic knots of quartzofelspathic material, occurs in belts among the "Moine schist." Augen-gneiss, or foliated porphyritic granite, occupies an area of about 3 square miles, making up part of the well-known mass of Inchbae. A few small outliers of Old Red Sandstone and Conglomerate also occur in the eastern part of the area.

"Moine schists" and "Muscovite-biotite-gneiss," which make up three-fourths of the area, may be looked on as the country-rocks. As these rocks are continuous with those already noticed in previous Reports,* a full description of them need not be given here. It is only necessary, therefore, to repeat that the rocks are for the most part isoclinally folded, with the limbs of the folds dipping eastwards. In spite of this deceptive appearance of an upward succession towards the east, it can be demonstrated that the same beds are folded upon themselves so rapidly that they extend over broad belts of country measured across the strike. In the eastern part of the area the long axes of the folds, and consequently the strike of the strata, are from N.N.E. to S.S.W., while in the western part the strike is N. and S., and sometimes N.N.W. and S.S.E. It is towards the western limit of the area that thin belts of Muscovite-biotite-gneiss occur, which are continuous with belts already traced through the ground to the south from near the head of Loch Luichart, where the evidence is in favour of the belief that the separate belts belong to a single band appearing in different folds, and separated into isolated portions by denudation.

* *Summary of Progress* for 1898, pp. 7-9 ; and for 1899, p. 7.

Mr. B. N.
Peach.

Of the well-known mass of intrusive Augen-gneiss or foliated porphyritic granite at Inchbae, about 3 square miles come into the district surveyed by MR. PEACH last year. The general character of this rock, together with its behaviour to the other schists which have already been described,* are well displayed in this district. The rock here also becomes finer grained, loses its porphyritic crystals near its junction with the schists, and sends out apophyses which penetrate the schists in the form either of sills that conform more or less to the original bedding planes of the schists, or of dykes that cut these planes. The granite appears to have produced a certain amount of contact alteration in the schists, though this early metamorphism is now masked in part by the structures that have been induced both in granite and schist by the pressure to which they have been alike subjected, and to which in great part, if not wholly, their present crystalline condition is due. In tracing the boundary-line of augen-gneiss it became apparent that the granite over a wide area lies in contact with the same band of rock, and that great irregularity of the boundary between them has been caused by the effects of denudation upon a highly plicated line of junction which displays a succession of isoclinal folds. Further, the available evidence supports the inference that in the area which has been mapped only a single line of contact is exposed, viz., that along the upper surface of the granite. The intrusive mass has, therefore, in all probability the form of a sheet or sill the bottom of which is not here laid bare.

Mr. C. T.
Clough.

The crystalline rocks in the west of Inverness-shire between Loch Duich and the hills of Knoydart are undergoing examination by Mr. C. T. CLOUGH, who reports that most of the area which has been surveyed near Loch Duich is composed of rocks that probably belong to the Lewisian gneiss, but that siliceous granulitic schists belonging to the "Moine series" are mixed and repeatedly folded with them. The axial planes of most of the folds incline E. or S.E.

Of the many types of rock referred to the Lewisian gneiss the following are among the most noteworthy :

1. Marble with silicates of lime and magnesia.
2. Eclogite.
3. Hornblende-schist, with or without garnets.
4. Biotite-gneiss or schist, with or without garnets.
5. Graphitic gneiss.
6. Pyroxenite.
7. Finely laminated rocks with some resemblance to mylonites.

The rocks next the outcrops of marble vary in character in different places. On the N.W. side of Beinn Fhada the adjacent rock is sometimes pyroxene-gneiss; at Totaig sometimes garnet-amphibolite, or thin banded hornblendic gneiss, or pyritous schist with brown mica. Near Carr a garnetiferous biotite-gneiss or schist comes very near one side of most of the outcrops.

* *Summary of Progress for 1898*, p. 9.

Many of the hornblende-schists are intimately connected with the eclogites, and form margins to them, or traverse them in thin bands, which seem to represent lines of shear. Others form parallel bands, sometimes hardly an inch thick, separated by bands of pale acid gneiss of nearly the same thickness. One hornblende-schist, on the E. side of Eilean Donnan, cuts the first foliation of an acid biotite-gneiss, and is perhaps of the same age as the "Scourie dykes" of Sutherland. Mr. C. T. Clough.

Some of the biotite-gneisses or schists near Carr contain biotite (often of a brown colour) in great abundance, and might be mistaken for micaceous "Moine-schists." They are, however, veined with many pale grey acid streaks, resembling foliated pegmatites. These streaks are more abundant than the pegmatites in the neighbouring "Moine-schists," and differ from them in being for the most part finely granulitic. Hornblende-schists are also sometimes interbanded with the biotite-gneisses, though it is not certain that they ever occur in the neighbouring Moine series.

The garnets in the garnetiferous varieties of biotite-gneiss are very abundant, and sometimes measure an inch across. Closely associated with these gneisses there are areas—sometimes as much as 3,000 square yards in extent—in which the rock chiefly consists of garnet and quartz. Crystals of kyanite, or lumps of small green micaceous scales—corresponding, perhaps, to the "shimmer aggregate" of MR. BARROW*—which seem to replace kyanite, frequently occur, both in the garnetiferous biotite-gneiss and in the peculiar rocks just described. In one locality there are exposures, several square yards in extent, which consist almost entirely of garnet and kyanite, or of garnet and the green micaceous scales, in nearly equal proportions.

The graphitic gneisses† are usually pyritous, and so deeply weathered that it is difficult to procure good specimens. It is clear, however, that many contain diopside or some allied mineral. About 130 yards S.S.E. of the S.W. end of Lochan an Beinne Faide,‡ a seam unusually rich in graphite, and perhaps averaging 8 or 9 inches thick, can be traced for about 30 yards. Another good locality for graphite occurs 730 yards W.N.W. of the S.W. end of the same loch. The graphite here is very irregularly distributed, and occasionally occurs in masses an inch or two in length and breadth, which seem mainly composed of much crumpled scales, some of which are more than an inch long.

Intrusive dykes, striking W.N.W. and N.W., are abundant on the S.W. side of Loch Duich, but rather rare on the N.E. side. Some are composed of mica-trap, some of hornblende-biotite-

* *Quart. Journ. Geol. Soc.*, vol. xlix. (1893), p. 340.

† Graphite has also been noticed within siliceous lumps in marble, and in eclogite.

‡ This seam was pointed out by MR. MURDO MURCHISON, the game-keeper at Tigh Dhruideig. The name of the loch referred to is taken from the Ordnance Maps, but MR. MURCHISON states that it is incorrect.

Mr. C. T.
Clough.

porphyrite, and some of felsite. A few dykes, with a nearly E.—W. direction, have a dark basaltic aspect, but some of them contain large flakes of biotite, and, perhaps, belong to the lamprophyre group.

Turning now to the region on the south side of Loch Hourn, where he has recently been at work, Mr. Clough remarks that most of the rocks in that district, so far as yet examined by him, belong to the type which was named by the Geological Survey the "Moine schists," none seeming to be referable to the Lewisian gneiss. A tract of at least nine or ten square miles is composed of a group of foliated rocks, most of the members of which contain a great proportion of mica, both biotite and muscovite. This group may provisionally be called the Ladhar Bheinn group, while the other more siliceous rocks, on either side of Ladhar Bheinn, may be classed together as the Beinn na Caillich group.

The Ladhar Bheinn micaceous schist or gneiss contains crowds of small garnets, usually the size of small shot, and small patches of garnet-sand are common in the alluvia. In the micaceous beds needles of tourmaline are here and there abundant, as on the coast 150 yards S.E. of Eilean a' Mhuineil, where some of them an inch long are bent and broken. Mixed with the micaceous portions there are in some localities bands of granulitic siliceous schist, which contain few or no garnets, and which seem even more siliceous than most of the Beinn na Caillich group. Numerous thinner garnetiferous siliceous bands, rarely more than four or five inches thick, contain conspicuous needles of hornblende, lying at various angles, and frequently across the foliation; also zoisite [9113].* These bands with hornblende and zoisite, are rudely parallel to one another, and sometimes also to other bands. This arrangement seems to indicate bedding, and probably the rocks represent altered sediments. The bands project conspicuously from many of the weathered rock-faces, and frequently show contortions which otherwise might escape notice. On the limbs of some of the folds they become attenuated, and sometimes altogether disappear. MR. TEALL states that they are allied to the zoisite-amphibolites noticed in Ross-shire by MR. GUNN,† but that some of them are more siliceous than the Ross-shire types.

After making allowance for folding, it still seems probable that the Ladhar Bheinn group was originally very thick. At the head of Coire Dhorcail its members form crags more than 1,000 feet high.

The Beinn na Caillich group is no doubt a continuation of the siliceous schists which on the N. side of Loch Hourn make up a large part of Ben Seriol. Both biotite and muscovite commonly occur in the rocks, but in small quantity compared to the granulitic material. Bedding is often indicated by variations in the proportions of mica, and in some places also by thin dark

* Figures in square brackets refer to the microscopic slides in the series of Scottish rocks in the collection of the Geological Survey.

† *Summary of Progress for 1897*, p. 41.

streaks, generally less than an inch thick, which are rich in grains of ilmenite [9119]. In addition to irregularities in the bedding which appear to have been caused by deformation during contortion, there are others which may be due to original false-bedding. In many places the laminae composing the apparently false-bedded bands seem to have been arranged in curves before the bands themselves were folded.* In some parts of the group, grains, both of quartz and felspar, probably represent clastic grains. Although to a considerable extent granulitized, they project somewhat on weathered faces, and can also be distinguished from the matrix by their freedom from micaceous scales. They are often in the form of short rods, with cross-sections less than $\frac{1}{8}$ inch in diameter. Sharply distinguishable from these grains, small spots of secondary felspar may be observed in some of the more micaceous beds of the group. They are generally quite free from granulitization.

Mr. C. T.
Clough.

The boundary between the Ladhar Bheinn and the Beinn na Caillich groups is not a sharp line. An intermediate zone, often from 50 to 100 yards wide, is composed of thin alternating bands, some siliceous and others more micaceous, many of them not more than an inch or two thick, but traceable for considerable distances.

It appears that at the present ground-surface the Ladhar Bheinn group is underlain on both sides by the siliceous schists of the Beinn na Caillich group, and the impression is given that the former are lying in a syncline of the latter, and are therefore of younger date. It is possible, however, that they lie in the central portion of a great fan-shaped fold, and that they were originally below the other group. On this view they would occupy somewhat the same horizon as other micaceous beds, which on the north side of Loch Hourn frequently occur between the Lewisian gneiss series and the siliceous Moine schists. On Ladhar Bheinn, however, the micaceous beds must be much thicker than any yet seen on the north side of Loch Hourn.

A mile or more west of the Ladhar Bheinn mass there is a broad band of schist, most of which differs from the common types found either in the Ladhar Bheinn or the Beinn na Caillich groups. A great part of this band is finely bedded, and contains many thin micaceous schists, which are crowded with small spots, the size of shot or small peas, of secondary micropoikilitic felspar. These spots closely resemble certain others already mentioned, which occur not far from the passage zone between the Beinn na Caillich and Ladhar Bheinn groups, and, as the beds on either side of the band are siliceous schists of much the same character, it seems possible that the band is due to repetition by folding, partly of beds near the passage zone and partly of Ladhar Bheinn beds. But none of the peculiar thin beds

* It has long been noticed that in many unaltered Torridonian grits and other sediments, the minor laminae are often sharply curved, even when the bands which they compose are nearly horizontal. See Sir A. Geikie's *Textbook of Geology*, 3rd edit., fig. 197

Mr. C. T.
Clough.

with hornblende and zoisite have yet been noticed in it. The band is exposed on the coast between Ceum Garbh and Rudha Ruadh, and has been traced S.W. to Gleann Ghuserein. Its width is frequently about half a mile, but the boundaries are somewhat indefinite. The portions which most resemble Ladhar Bheinn schists increase in a S.W. direction, and are exposed over large areas on the N. side of Gleann Ghuserein, near the Priest's Pool.

In the district S. and S.E. of Barrisdale on Loch Hourn numerous pegmatites may be noticed, some of which are as much as thirty yards wide. Many are of very acid composition, and contain much quartz, as well as large plates of white mica, while others present brown mica and plagioclase feldspar. Besides the broad pegmatites, many of which behave like dykes and cut the foliation and bedding, thin streaks and lenticles of pegmatite may be observed, which usually keep along the foliation-planes, and, in some places, occur in such numbers that, though rarely more than half an inch across, they form about half the rock and convert it into an "injection gneiss" or "vein-gneiss" ("aderngneiss" of Sederholm.*) The thin, sill-like pegmatites are not necessarily accompanied by the dyke-like pegmatites, nor are the latter by the former. The sill-like seams are often disposed in sharp folds, and foliated across their sides in directions parallel to the axial planes of the folds, but the dyke-like bands often cut straight through folded beds and folded quartz veins. One or two dyke-like bands have been noticed to cut others of the sill type, though they seem to be of much the same composition.

In the part of the district displaying many pegmatites a few thin bands of granite-gneiss may also be seen, which cut the bedding. In the Ladhar Bheinn group on the coast between Eilean a' Mhuineil and Inbhir Dhorcail, in close association with the bands which contain hornblende and zoisite, a few thin beds of hornblende schist, none more than a foot thick, may possibly represent intrusive sills, but none has been noticed to transgress the bedding. There are a few thicker hornblendic bands, of variable composition, which are only occasionally foliated. With one doubtful exception all these lie E. of a line drawn N. and S. through Ladhar Bheinn. Like the hornblende intrusions in the Moine rocks on the N. side of Loch Hourn,† they generally cut the bedding-planes, and occasionally at right angles. Some of them are crowded with quartz-veins, as much as a foot or two broad, the marginal portions of which are frequently penetrated by long crystals of albite or oligoclase [9109 and 9110].

The intrusive masses which are never foliated may be divided into three groups. 1. Mica-traps and lamprophyres: in dykes

* "Über eine Archaische Sediment Formation im südwestlichen Finland," p. 133.

† *Summary of Progress for 1899*, p. 16.

with a nearly E.—W. direction. 2. Basic dykes of uncertain age. Mr. C. T. Clough.
 3. Dykes and sheets of Tertiary age.

The intrusions of the first group are somewhat rare in all parts. The dykes of the third group are very common in the W. part of the area, but rare further E. They strike N.N.W., and are composed of basalt and dolerite, or more rarely, of a rock allied to trachyte.

The dykes of the second group have only been noticed in the E. part of the area. On first inspection they appear like some Tertiary dykes, but they generally strike nearly E. and W., and contain small oval reddish or pale grey patches, often a quarter or half an inch long, in which occur small crystals of hornblende. Some—possibly all—of these patches have an amygdule near the centre. It seems probable, on the whole, that they belong to the lamprophyre group, but some are in a very fresh condition for such rocks. MR. TEALL states that they contain, in addition to the hornblende, more or less idiomorphic augite, together with occasional biotite and pseudomorphs after olivine [9111 and 9112].

The district in which MR. LIONEL W. HINXMAN has been mainly Mr. L. Hinxman. at work during the past year stretches southwards from Strathconon across Glen Strath Farrar to Strath Glass, and is entirely occupied by crystalline schists of the Central Highland type with their associated igneous intrusions. The lithological characters of these rocks and the general structure of the ground were fully discussed in the *Summary of Progress* for 1899, and the work of last year has revealed few facts of importance to add to that description.

The system of folding in Strathconon is of a more complex type than that which obtained in Glen Strath Farrar, and rapid changes in the pitch and direction of the long axes of the folds give rise to greater irregularity in the outcrops and areas occupied by the different zones in the former region. An important structural line of disturbance crosses the N.W. corner of the ground, and has evidently determined the N.E. course of the river Meig between Milton and Inbhir Chorrainn. It is accompanied by a sudden deflection of the strike and a considerable amount of crushing along the eastern bank of the river. It is evidently a continuation of the line of fault or lateral wrench mapped by MR. PEACH in the ground to the north, and described by him in the *Summary of Progress* for 1898.

A small belt of rocks, distinctly separable in character from the muscovite-biotite-gneiss with which they occur, is exposed in the stream and at the foot of a crag near the road at Balnult in Strathconon. These fine-grained granulitic gneisses have a regular banded appearance, contain a large amount of epidote, and though generally acid, include several thin hornblendic bands. They appear to be separated from the overlying muscovite-biotite-gneiss by a line of movement and crush, along which the rock is very finely granulitic and even platy in structure. They strongly resemble in character certain gneisses of presumably Lewisian age further to the west.

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A much larger outcrop of banded granitic and granulitic biotite- and hornblendic gneiss crosses the upper part of Glen Strath Farrar, one mile west of Broulin Lodge. The rocks are well exposed in the Allt Toll a' Mhuic, and from the lower part of the precipitous eastern face of Sgùrr na Muice, where they appear to dip beneath the flaggy siliceous "Moine schists." The further limits of this band have still to be traced, but it is known to extend westwards up the valley to the Uisge Misgeach, and probably forms part of the large mass of Lewisian gneiss mapped to the north of the river Meig and Loch Beanachan by MR. PEACH.

With regard to the igneous rocks of this district, it may be observed that sills of garnetiferous amphibolite are largely developed about Scatwell in Strathconon, where they are associated with the highly siliceous members of the "Moine schist" series. They die out rapidly to the westward, and higher up the valley are represented by small isolated lenticular masses. Some of these are full of very large garnets, and of amorphous lumps of garnet mixed with quartz and other minerals, and surrounded with a deep black mica—probably Haughtonite.

A small outlier of the Glen Orrin granite has been mapped on Meall Mòr, $1\frac{1}{2}$ miles W. of the main mass. The intervening ground is full of small intrusions of granite and pegmatite, but beyond the immediate neighbourhood of these masses there is a striking absence of acid igneous material in the rocks between Glen Orrin and Strathconon. Several sills of mica-trap are found in the Moine schists of Strathconon, Glen Orrin, and Strath Glass. They have a uniform E. and W. trend; and though rarely exceeding two or three yards in breadth, often form conspicuous green features along the hill-sides.

Several mineral-veins are found in the Moine schists on the western side of Strath Glass between Struy and Crelevan.* They occur as veins of calcite containing abundant galena, zinc-blende, and barytes; and are associated with lines of fault-breccia that run nearly E. and W. approximately at right angles to the strike of the schists. The mineral-veins do not appear to be more than 2 to 3 feet in thickness, and have an average dip of 60° .

The lead ore was at one time worked to a considerable extent, but owing to difficulty of carriage the mines have long been abandoned.

A thin vein of plumbago, also worked many years ago, occurs in the muscovite-biotite-gneiss of Glen Strath Farrar, between Loch a Mhuilinn and Loch Bunacharan.†

* Heddle states that "crystallised galena occurs in glen, two miles from Struy Bridge, in barytes."—*Mineralogy of Scotland*, p. 17.

† The occurrence of this mineral here has long been known. JAMESON mentions that "it occurs in imbedded masses and disseminated in gneiss in Glen Strath Farrar, in Inverness-shire." *Manual of Mineralogy* (1821), p. 118. In HEDDLE'S work just cited, the following statement occurs as to the working of the graphite at this place:—"In 1818 five tons were extracted, which sold for £93 each; the cost of raising was £13 per ton. It is associated here with felspar, quartz, mica, and garnet. The rock near the old workings now shows only scales of graphite taking the place of mica."

Veins of rose-quartz are met with in masses of garnet-amphibolite at one or two localities in Strathconon.

Torridonian.

The only district in which rocks of recognisably Torridonian age were mapped last year was in the island of Scalpay, on the east side of Skye, where the ground was mapped by MR. ALFRED HARKER. The Torridonian rocks cover the greater part of the island. The principal stratigraphical group represented by them corresponds with the Applecross group, and consists of coarse reddish felspathic sandstones, mostly pebbly, and often current-bedded. The lower division consists of finer-textured sandstones, often flaggy, felspathic in the upper part but quartzose in the lower. The normal dip is N.W. at about 20°; but there are local disturbances of Tertiary date, especially a broken synclinal, forming Mullach na Càrn, the highest ground in the island. The Cambrian limestones and quartzites are not found in Scalpay, and the relation of the Torridonian to the great post-Cambrian disturbances cannot be made out. It seems probable, however, that the rocks are overthrust, for on the Skye side of the Sound, only $\frac{1}{4}$ mile distant, the corresponding beds (the lower quartzose members) are seen resting upon Cambrian limestones. Mr. Harker.

Dalradian or Younger Schists of the Scottish Highlands.

ABERDEENSHIRE.

MR. BARROW resumed in the early summer the mapping of the remote mountainous region at the head of Glen Tilt (which has an interest to geologists from the visit paid to it by HUTTON*), but, as already stated, was soon disabled by severe illness. He has supplied, however, some notes of the geology of the ground, based partly on previous examination. As shown in the stream-sections, the rocks have been intensely folded, the majority of the folds being of the isoclinal type, with limbs dipping at a high angle. A local peculiarity of these folds is that their crests are frequently seen just at the junction of two beds, so as to show which beds lie next each other. Thus the junction of the honestones and the quartzite is repeatedly exposed. The former are, moreover, at times so thin that they can be seen to lie between the limestone and the quartzite, and thus the order of three members of the succession can be determined. These honestones gradually pass into the dark schist so frequently associated with the limestone. The change in the material that lies between the limestone and the quartzite is occasionally remarkably sharp, while if the rocks are followed along the strike Mr. George Barrow.

Mr. George
Barrow.

of the folds it can often be seen to take place quite gradually. It should be remembered that the folds in the Highland rocks are of such depth that outcrops now close together were originally a considerable distance apart, so that the appearance of a sudden change may be entirely deceptive. The local variations in the bed next the limestone, where they can be followed along the strike, are not more rapid than those in the Yoredale rocks, and distinctly less rapid than those in the Lower Oolites of East Yorkshire. A dark schist, which is found on the side of the limestone furthest removed from the quartzite, can be identified from place to place by the fact that a well-banded rock composed of laminæ alternately poorer and richer in lime intervenes between it and the limestone, though where this rock is hidden by drift, it is not possible to say with which dark schist we are dealing.

Two intrusions of the older granite have been met with in this district. One occurs about a mile above Falar Lodge, and is cut through by the Falar Burn. Seen from a distance of about 100 yards, this rock presents the appearance of bedded sedimentary material dipping at a high angle. On closer inspection this appearance is seen to be due to the perfect foliation of the intrusion. The rock is now an augen-gneiss, composed of oval crystals of felspar wrapped round with dark mica. The larger felspars are either microcline or orthoclase, and the rock is identical with the Meall Gruaim augen-gneiss, from the lower end of Glen Tilt, described by MR. TEALL some years ago. Though this rock is so loose that much of it can be picked to pieces with the fingers, small cores can easily be met with from which sections can be cut, and these are seen under the microscope to be singularly fresh and unaltered.

The other example of these intrusions, which occurs near the Tilt valley, is the only case of the occurrence of this material not exactly along the line that intersects the belt of hornfels-alteration that has now been proved to extend for so great a distance, though it does not lie far off this line. It is less foliated on the whole than the augen-gneiss.

A number of thrust-planes have been detected around Falar. Now that the sequence of the rocks of the region is known, it may be inferred that the amount of displacement is usually small. The rocks intersected by these dislocations are highly schistose close to the face of the planes of movement, and have there acquired a thoroughly crystalline structure. The effects of the small thrust-planes are best shown by the quartzite. Owing to its hardness this rock has offered great resistance to crushing, consequently cores of white uncrushed quartzite are still seen in the mica schist. That the mica has been produced at the expense of the felspar material in the quartzite is well displayed, for distorted pebbles can be seen converted apparently entirely to white mica.

The fact of the occurrence of a number of minor thrusts leads to the suspicion that a major thrust-plane may exist in the district. The evidence seems fairly conclusive that a

powerful thrust runs in the bed and along the west side of the upper Tilt. At the head of this long, singularly straight valley a striking contrast may be seen between the shapes of the two sides. The western shows a perfectly uniform slope, as if cut with a machine, at once suggesting the presence of a sole or surface of a thrust-plane. The other side of the valley is totally different in form, being sometimes precipitous, at other times presenting an easy slope. Indeed, the east side of the valley looks rather like an irregularly-shaped escarpment, with the sole outcropping from beneath. An examination of the rocks on the east side at the bottom of the valley shows that they become intensely schistose as they approach this sole. Mr. George Barrow.

These facts have been obscured by the much later Glen Tilt fault, which is essentially a normal one. It is accompanied by the usual angular shattering of the rocks, which has led to their decomposition, and has thus obscured their relations to each other. But for this circumstance, the presence of the proofs of some earlier movement, differing in its effects from a normal fault, would, no doubt, have been suspected long ago by some of the peculiarly able observers who have from time to time visited Glen Tilt. The normal fault is mainly older than the intrusion of the granite, as is shown by the abundant short dyke-like intrusions of that rock. But, as in the more northerly portion of its course, there have been post-granitic movements which have at times greatly crushed these intrusions.

It may be remarked in conclusion, that the stream-sections in the upper part of the Glen Tilt region have undergone a singular change since the members of the Geological Survey first examined them. They were remarkably clear and accessible when some years ago they were visited by MR. DAKYNS and MR. BARROW. For a number of winters before that time the snow had melted in such a way as to slide down the steep sides of the gorges in great masses, tearing up any small trees that had begun to grow, and often taking with it the soil also. The banks of the gorges were thus mostly bare rock. For some unexplained reason this has not happened for at least ten years. On reaching Falar Lodge last June, MR. BARROW was greatly astonished to see the sides of the stream densely wooded with small birch trees, which, as they have grown up, have arrested the downwash on the sides of the ravines, thus affording soil for the growth of grass. The Falar Burn in its lower part was from this cause quite unrecognisable. Many of the sections are now quite obscured, of which, fortunately, drawings and photographs were formerly taken.

While engaged for a short time in the early part of the summer tracing the limits of the basic portion of the Cairngorm granite between Glen Gairn and Crathie on Deeside, and in joining up lines with MESSRS. BARROW and CUNNINGHAM CRAIG on the N. side of the Dee, MR. HINXMAN found that the separation of the basic modification of the granite from the typical acid granitite is attended with considerable difficulty, owing both to the gradual passage of the one rock into the other, and to the Mr. Hinxman.

Mr. Hinx-
man.

drift-covered nature of much of the ground. In some localities and especially at Balfentaig and near Rechrachrie in Glen Gairn, the line between the flesh-coloured granite and the dark quartz-mica-diorite with sphene is more or less sharply defined. Elsewhere there is an insensible gradation from the acid into the more basic rock, and specimens taken from various parts of the same mass will show an ever-varying amount of basicity. On the hill slope above the upper part of the Crathie Burn, and N.N.W. of Bridgend of Bush, the rock varies within a small area from a fine-grained diorite, chiefly composed of hornblende, to a coarse quartz-biotite-diorite or hornblende-granite, rich in potash felspar in the form of large crystals of pink orthoclase. Both acid and basic rocks are traversed by small later intrusions of a fine-grained grey rock with porphyritic felspar phenocrysts, belonging to the lamprophyre group.

Some interesting phenomena of thermo-metamorphism were observed in this region. The main mass of Culardoch, a conspicuous hill which rises on the S. side of the Gairn to a height of nearly 3,000 feet, is made up of highly altered sedimentary rocks. Garnetiferous mica-schists are found at the northern end; while the summit and steep southern face are covered with angular blocks of dark, ferruginous andalusite-hornfels sometimes containing tourmaline. It is evident that we are here dealing with altered phyllites and black schists of the Banffshire series, while there can be little doubt that this metamorphism is due to the Cairngorm granite which, in its more basic form, almost entirely surrounds the hill and crosses its S.E. shoulder in close proximity to the hornfels.

Intense contact-metamorphism was also observed in the Knoch of Lawrie, in connection with apophyses of the newer granite. Limestone bands have been converted into green calc-silicates, while the accompanying black schists pass into cordierite-hornfels, in which the characteristic puckering of these schists can still be detected.*

In connection with these observations on the Aberdeenshire ground, reference may here be most conveniently made to the results of a re-examination of part of the district of Strathspey by MR. HINXMAN together with MR. GRANT WILSON. Further study of the igneous masses of Hunt Hill and Netherly on the Burn of Rothes tends to prove that there is here a basic modification of the ordinary acid granite, similar to that met with in connection with many other intrusions of the newer granite. The basic rock is a coarse-grained quartz-mica-diorite, the biotite often occurring in very large individuals. The granite is of the usual Cairngorm type, and forms a complex with the surrounding sedimentary rocks, which are much impregnated with granitic material. The relations of these two types are nowhere clearly

* MR. CUNNINGHAM CRAIG'S account of the contact-metamorphism of this region and his description of recent work among the Cairngorm granites are given at pp. 19 *et seq.*

visible on Hunt Hill, but along the roadside between Dandaleith and Craigellachie Bridge an apparent passage can be traced from a basic rock resembling the Netherly diorite into the red granite of the Rock of Craigellachie. Mr. Hinxman.

The district of Aberdeenshire surveyed last year by Mr. CUNNINGHAM CRAIG, lies north of the River Dee, between Crathie and the Feardar Burn. It is chiefly remarkable for the number and variety of its igneous intrusions, the relations of these intrusions to each other, and their metamorphic effects upon the surrounding and included rocks of sedimentary origin. Mr. Cunningham Craig.

More than five-sixths of the ground, where free from drift, is occupied by igneous rocks, nearly all of which are holocrystalline, and all of which can be assigned with certainty to the age of the newer granites and diorites. The district lies just outside the area of the larger granitic tracts, being situated directly between the granite mass of Lochnagar and that of the eastern extension of the Cairngorm Mountains. The intrusions are for the most part comparatively small, and have been introduced at slightly different epochs in the period of igneous intrusion; it is evident that introduction of igneous material has taken place from a differentiating magma, and while no clear evidence of differentiation *in situ* has been obtained, many minor phases of the magma are represented.

The igneous rocks may be classified primarily into (1) Diorites and their apophyses, and (2) Granites and their apophyses. The various masses are very irregular in form at the surface, but often spread out into sheets, or sill-like forms, such as are so characteristic of the newer granites in the Braemar district.

The diorites are the earliest intrusions in this district. They vary in composition from a fairly basic diorite containing augite to a rock containing rather more biotite than hornblende, and which may even contain quartz, thus merging into the granitic type. All these plutonic rocks may have their fine-grained apophyses, as dykes or marginal belts, which range from camp-tonites to quartz-porphyrates.

Into and through these intermediate rocks biotite-granites, which also vary perceptibly in composition, have been intruded, and these more acid phases of the magma have occasionally, though much more rarely than the diorites, their fine-grained apophyses, eurites, aplites, and quartz-porphyrates. Where a considerable mass of granite comes in contact with the dioritic rocks, the latter are frequently seen to have been fused or partially fused, so that an intermingling of the materials of the two rocks has taken place. This intermingling may have been assisted by chemical action. Specimens showing the incipient intermingling may be obtained in many localities, but more frequently the interfusion has been more complete, and a new rock, partaking of the nature of both granite and diorite, has been formed. As these mixtures of igneous material may have taken place between any variety of diorite and any variety of granite, it is evident that many rocks to which it is difficult to assign a name may occur. The belts

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of composite rocks of this nature never attain any great breadth on the surface, but are usually well defined, and have been mapped wherever this was possible, and distinguished from the diorites and granites. Some varieties have been mapped as tonalite; but the term is not often applicable, the usual type being a quartz-plagioclase-biotite-hornblende rock, often with large crystals of pink orthoclase—a hornblende-granite.

In many cases, where the conditions were not favourable, though the evidence is often insufficient to enable a cause for this to be determined, no interaction has taken place between the diorites and granites. In these cases the granitic intrusions are usually small; it is possible that the "quantity of heat" available was insufficient to fuse the earlier rock. Certain fine-grained intrusions may represent the dyke phases of the composite rocks, such as a quartz-porphyry with hornblende phenocrysts on Creag an Ordaigh. The hornblendes may, however, have been derived from the diorite through which the quartz-porphyry has been intruded.

Besides the larger irregular intrusions, dykes and veins are numerous in this area, especially those of acid material from the granite. In some localities, in a felspathic biotite-gneiss, the granitic veins become so frequent that the rock may be said to be permeated with igneous material, the crystalline constituents of which often "dovetail" with the crystalline constituents of the metamorphosed rock, giving an indistinct or welded junction. The material of these veins varies from a fine white aplite to a fairly coarse granitic pegmatite, while a faint pseudofoliation may be observed occasionally. Where the diorites are cut by the same veins the junction lines are sharp, and no trace of parallel structure in the veins is noticed. The areas where permeation has been observed can be traced with occasional gaps and intervals, where one of the larger intrusions occupies the surface or where the ground is drift-covered, for several miles to the westward and south-westward to Creag a' Chleirich, north of Braemar, where the permeation by granitic material beneath the sill of Auchindryne granite has been previously noted. (*Summary of Progress*, 1898, p. 32.)

With regard to the metamorphic effect of the igneous intrusions, the evidence is here strikingly complete. The area is one of slowly-cooled plutonic masses, quickly-cooled dykes being the exception; and so largely do igneous rocks occupy the surface of the ground that no exposure of original sedimentary rock has been observed at a distance greater than a hundred yards from one of the larger igneous masses. This is the measurement in a horizontal direction; measured vertically, the distance can usually be proved to be very much less, as the patches of metamorphic rock lie frequently above the intrusions, or, preserving their natural strike, are wedged between separate intrusions, *e.g.*, of granite and diorite. Lines of inclusions of metamorphic rock, maintaining a regular strike, can be traced in this manner along the hill sides. As might be expected under such circumstances every rock, which from its composition

is susceptible of thermo-metamorphic change, is profoundly altered.

MR. BARROW (*Summary of Progress for 1899*) has called attention to the exceptional extension of cordierite-hornfels in this area outside the great granitic masses of Lochnagar and the Cairngorm Mountains. The aluminous black schist, wherever it appears in this area, is changed into hornfels, either as cordierite, andalusite, or kyanite-hornfels, often with a great development of contact biotite, all schistosity being obliterated, while the somewhat aluminous quartz-biotite-rocks appear as rusty banded gneisses or hornfels, containing sillimanite. Even the pure quartzite is greatly affected, presenting on a fresh fracture a coarse mosaic of glassy clear quartz, in which occasional felspar blebs may be detected. The bedding, except where colour-banding occurs, has been obliterated.

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The metamorphism of the limestone, however, is perhaps the most striking test of the extent to which thermo-metamorphic processes have proceeded. The late Dr. Heddle has made the limestones of Creag Mhor, Creag Bheag, Creag an Ordaigh, with their magnificent development of silicates, well known; masses of garnet, idocrase, malacolite, wollastonite, etc., are the rule rather than the exception in the less pure bands, while those bands too pure to give rise to silicates are converted into a white marble, in which the individual crystals are sometimes as large as peas.

A remarkable case of interaction between an igneous and a sedimentary rock, or of the absorption of the latter by the former, has been observed on Creag Bheag, a mile north-north-west of Inver, where the diorite comes in contact with a considerable mass of limestone. For a distance of fifty yards the margin of the igneous rock is modified in a peculiar manner for a depth of not more than three or four yards. The section is not sufficiently well exposed to admit of all the evidence being made clear, but enough to establish the main fact has been obtained. The diorite inside this marginal zone is a normal fine-grained diorite, with some biotite, dark in colour, and showing no abnormal arrangement of the minerals. At the marginal belt, the character of the igneous mass changes rapidly but by perceptible gradations, the rock becoming an augite-diorite of a peculiar type. The material has a mottled appearance owing to the development of large ill-defined plagioclase crystals in a matrix composed of green lath-shaped crystals of diopside and felspar, with hornblende, quartz, and sphene in lesser quantity. The crystals of sphene sometimes attain a large size. Biotite is occasionally present near the passage into normal diorite.

MR. TEALL has examined specimens of this augite-diorite and has supplied notes on the microscopic features, from which the following remarks are taken:—

"[9124] Augite-diorite, composed of hornblende, diopside plagioclase, quartz, and sphene."

"[9126] Variety of the above essentially composed of pale green pyroxene, plagioclase and sphene (in very large individuals). Apatite, rendered almost opaque by inclusions, is also present."

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It is to be remarked that this modification of the diorite is a purely local phenomenon; it appears that some part of the limestone has been absorbed, thus modifying the composition and totally changing the aspect of the igneous rock. A somewhat similar rock, for which a similar mode of origin has been suggested, has been described by MR. HINXMAN. (*Explanation of Sheet 75, p. 27.*)

Cairngorm Granite.—In the area of Cairngorm granite and contiguous flaggy biotite-gneisses surveyed last year in Sheet 64, the most interesting point is the occurrence of certain white muscovite-pegmatites in the metamorphic rocks. These pegmatites are confined to the area to the north-west of the great Clais na Fhearna fault, and with the exception of a few minute veins, all occur within a distance of a mile from the granite margin, but their petrological characters are so distinct from any intrusion recognisably connected with the granite mass, as to suggest a different origin. These pegmatites seldom attain a thickness of more than 4 feet, and can never be traced for any great distance; they usually follow the bedding of the country-rock in horizontal lenticles, though vertical veins are not infrequent. All exhibit a more or less distinct foliation and flaser-structure, which are more marked in the horizontal veins. The rocks consist of drawn-out lenticles of quartz and felspar, with plates and well-developed crystals of muscovite, surrounded by a granulitic matrix of quartz and felspar. Garnets are frequently present. Many parts of the veins are completely granulitised, especially towards the margins. In those veins which follow more or less closely the bedding-planes of the surrounding rocks, the foliation of the igneous material coincides with that of the metamorphic rock, while in the vertical veins the foliation frequently makes a large angle with the margins of the vein. From this relation it is evident that the foliation is not a protoclastic structure induced by flow during cooling, but has been developed by cataclastic action—a fact which suggests that these pegmatites are of earlier date than the granite. Evidence with regard to the Clais na Fhearna fault supports this view. Though all movement along this great line of disruption had not altogether ceased at the time of the intrusion of the Cairngorm granite, that mass of igneous rock is not very greatly affected, while the area in which these pegmatites occur in this district is bounded by the fault, as if they had been intruded prior to the dislocation. The state of metamorphism on the two sides of the fault does not differ greatly, though the country-rocks to the westward of the fault are obviously on a different horizon from those on the eastern side, as shown by the disappearance of solid quartzite bands.

MR. TEALL has examined microscopically two specimens from the foliated pegmatites, and calls attention to the absence of potash-felspar. The specimens consist of "grey granulitic biotite-gneiss" (the country-rock) "banded with white foliated muscovite-pegmatite, composed of large plates of muscovite, and sometimes large crystals of oligoclase, embedded in a fine-grained

granulitic aggregate of quartz and oligoclase." The granulitization, foliation, and banding with the country-rock point to a common metamorphism. The behaviour of the muscovite, taken in connection with the absence of potash-felspar, confirms this view. The large muscovite plates and crystals are more conspicuous where the matrix is completely granulitised, or where there is evidence of the complete breaking down of crystalline groups of quartz and felspar. In some cases idiomorphic crystals of muscovite up to 2 inches in diameter have been developed across the foliation planes, and surrounded by the granulitic matrix. It is evident that such muscovites have not suffered from dynamo-metamorphism, they are probably secondary, and derived in great part from the destruction of potash-felspar broken down in the movement which preceded granulitisation. It may therefore be inferred that the pegmatites are older than the Cairngorm granite, and that a thermo-metamorphism has succeeded the shearing movement and affected alike the pegmatites and granulitic gneisses of the district.

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In the *Summary of Progress* for 1898 it was mentioned that the Clais na Fhearna fault—which is the great fault of Glen Tilt, Loch Tay, and Glen Ample—affects the Cairngorm granite in Glen Lui. It is not suggested that the intrusion of the granite was prior to the great faulting movement, but that some movement along this line of dislocation has certainly taken place since the intrusion. A small area at the head of Glen Gairn, surveyed this year, has yielded additional evidence of the fact that part of the movement has affected the granite mass. A precipitous gash, one thousand feet deep, which separates Creag na Dala Bige from Creag na Dala Mhor, marks the position of this line of disruption. Creag na Dala Mhor, the north-western side of the fault feature, is a spur of the granite massif of the Cairngorm mountains. At the mouth of this great natural trench, where it opens out into Glen Gairn, small exposures of granite are observed on the south-eastern side of the fault, and these show some signs of the crushing and veining common to the metamorphic rocks of the neighbourhood.

In the granite mountains to the westward, also, zones of minor crush-veins may sometimes be traced for miles, usually making well-marked features. As an instance, a zone containing many well-defined veins of this nature passes from the western flank of Beinn Bhrotain, north-eastward through Glen Geusachan, west of the Devil's Point, through Glen Dee, and breaks into many minor zones about the summit of Beinn Macdhuil.

No single crush-vein can be traced for any great distance, but the zone in which these veins have been developed is well-defined. Such zones run parallel to the Clais na Fhearna fault, and probably represent minor movements of approximately the same age and type.

PERTHSHIRE.

With a view to obtain more light on the structure of the central Highlands, the band of schists known to the surveyors

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as the "Green beds" has been picked out and traced across the region. This revision was carried last year by MR. CUNNINGHAM CRAIG over the ground on either side of the Tay below Aberfeldy. It has helped to clear up some points in the tectonic arrangement of the rocks, and has thrown fresh light upon their metamorphism. The outcrop of these green beds was followed from Pitlochry southwestward to Dull, where it descends to the alluvium of the Tay valley. Folded outliers and inliers as well as repetitions of the bands due to faults across the strike of the folds, afford evidence of great value in elucidating the structure. This ground lies to the southeastward of the great central axis of folding of the Perthshire and Aberdeenshire Highlands, so that only a part of one side of the "fächer" or fan-structure is represented, the overfolds being towards the south-east or south-southeast. The flexuring, though sharp, cannot be described as isoclinal in the strictest sense, since the different limbs of the folds can usually be distinguished by their angle of dip. Nor are the folds of any great "amplitude," i.e., the limbs of the folds are nowhere very long. The result is, that though the folding is not on a large enough scale to cause repetitions of the whole outcrop of "Green beds," where unaided by faulting, individual beds are repeated, and the outcrop is thus considerably broadened.

Another remarkable characteristic of the folds is that they are unsymmetrical, and consist of a longer limb the dip of which as a rule varies only a few degrees on either side of the horizontal, and a shorter limb inclined at a higher angle towards the north-west.

It is the development of the gently-inclined or larger limbs which gives to the area north of the Tay in which the "Green beds" occur the appearance of a flat step-feature lying to the south of the higher and more rugged line of hills formed of rocks higher in the succession, where the axes of the folds are more highly inclined. The same flat structure in the more uneven ground south of Aberfeldy gives a more complicated outcrop of the "Green beds." There are complications in the structure in this southern area which will be described more fully when the ground has been completely mapped.

Dynamic metamorphism in the stretching and shearing of material has had greater effect in the longer limbs of the folds than in the shorter limbs. It seems that this is due to the position of the longer, flat-lying limbs being more favourable to movement under lateral thrust. Subsequent or contemporary thermo-metamorphism has affected each bed differently, according to the different stages of dynamic metamorphism; the more a bed has suffered from the latter, the more susceptible it becomes to change under the former. In consequence, it is found that a bed where it is exposed in the longer limb of a fold, presents a different aspect from that where it is exposed in the shorter limb. These considerations are insisted upon, because their effect is to enhance the difficulty in many localities of distinguishing between "Green beds" and epidiorites in the field.

The "Green beds" in the area north of the Tay are represented by fine hornblendic schists, usually containing small wine-coloured garnets. The foliation is well marked throughout, and is occasionally emphasised by the development of biotite on the planes of schistosity. The rocks have not the appearance of irregularly sheared material, the schistosity is constant throughout, and each bed breaks more readily along joint-planes than along the foliation-planes. Quartz is sometimes observed to be present, but no traces of original gritty structures are to be seen. The appearance upon a fresh cross-fracture is that of a mesh of minute hornblende crystals orientated in the planes of foliation. Microscopic examination, except of crushed and powdered material, has not yet been made.

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In many localities, confusion is liable to arise between the epidiorites and the "Green beds" of this area. As a rule, the epidiorites are readily distinguishable by their coarse crystals and "eyes" of hornblende, and characteristic mode of weathering; but where only the margin of a sill or only the longer limb of a fold is exposed, the rock occurs as a fine, well-foliated, hornblende-schist, which closely approaches the "Green beds" in appearance. This is more particularly the case in small sills of fine-grained epidiorites, such as are to be seen both to the north and south of the main epidiorite outcrop, but many of these may be merely repetitions by folding of the margin of a larger sill. It is where faulting and folding have reduplicated such sills and brought them into the same line of strike with the "Green beds," in an area in great part concealed by drift, that the greatest difficulty of distinguishing these rocks is experienced.

The difficulty has been overcome by observation of the following characteristics. The epidiorites have a less regular foliation than the "Green beds," frequently showing zones of alternately more and less schistose aspect, while on a cross-fracture much drawn-out "eyes" of hornblende are occasionally seen. On a fresh cross-fracture the epidiorite sills usually show a greater lustre than the "Green beds," while, when crushed for microscopic examination, it is seen that the hornblende is of a darker colour than that of the originally sedimentary rock. Biotite occurs less frequently and more sporadically than in the "Green beds;" quartz has not been observed; carbonates, possibly derived by secondary change from saussuritised felspar, are sometimes present, while garnets are very seldom seen. The characters of the associated rocks and the fact that the epidiorites occupy a higher horizon in the succession, have also proved of assistance in the distinction of these sills from the "Green Beds."

A sufficient area south of the Tay has now been examined to prove that a considerable decrease in metamorphism takes place in that direction. The "Green beds" afford a good instance of this diminution, but the evidence from them is not more striking than that from the other rocks of the district. North of the Tay no traces of original pebbles in the rocks which were once grits have been observed, except in a few rare instances.

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In the area to the south original gritty structures begin to appear, and become more conspicuous as the beds are traced southward. At the same time, garnets are seen to decrease in size and number, and finally to disappear from many of the beds. When the ground has been more fully surveyed this decrease in metamorphism will be described in greater detail.

During the mapping of the "Green beds," all necessary revision in the localities examined was undertaken. In the course of this revision another interesting example of an acid igneous rock intruded before the shearing and granulitisation, has been disclosed. This rock is exposed on the ridge dividing the valleys of the Tay and Tummel, about two miles S.S.E. of Pitlochry. Its outcrop is irregular, but attains a length of upwards of half a mile, and can be traced as far as the drift and fluvio-glacial gravels of the Tummel valley. It appears to have the form of an irregular sill, intruded more or less along the bedding-planes of the surrounding rocks. Introduced subsequently to the folding, this igneous mass has suffered from the shearing movement which appears to have been in this locality the latest phase of the dynamic metamorphism. The Director-General, who visited this locality in October, pointed out that on the crests of folds the foliation due to this later shearing movement could be distinguished from the early foliation produced during the folding. In the limbs of the folds these foliations coincide. The foliation is seen to pass from the surrounding schists, into and through the igneous rock, proving that it is a cataclastic structure.

The main mass of this intrusion consists of a granulitic muscovite gneiss, composed of a fine-grained granulitic aggregate of felspar (not determined) and quartz, with flakes of muscovite (probably in great part of secondary origin), orientated in the planes of foliation. Microscopic examination of the rock has not yet been made. Nests and veins of more coarsely crystalline material are frequent, and, especially near the margins of the mass, sometimes attain the dimensions of regular pegmatite veins. In these the crystallisation is very irregular and confused, and the foliation is by no means so apparant, being sometimes indistinguishable. Small quartz-veins occur here and there in the main mass of the intrusion. Pegmatite veins are numerous just outside the main mass; small crystals of tourmaline have sometimes been observed in them. A few small veins of a similar nature, seldom exceeding a foot in thickness, have been noticed at wide intervals to a distance of two and a-half miles to the westward and south-westward.

The effects of any metamorphism due to this igneous intrusion cannot be distinguished. It is evident that, as in the case of the Glen Dee pegmatites described above, both the igneous and the surrounding metamorphic rocks have been metamorphosed since the intrusion. In this case, however, granulitisation has proceeded further, for all traces of broken crystals or flaser structures have been obliterated. The rocks of the district have all developed garnets during thermo-metamorphism, which

seem rather to decrease in number and size as the igneous rock and its pegmatites are approached. The garnets have crystallised since all shearing movement ceased, and are consequently of later age than the intrusion.

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DUMBARTONSHIRE AND STIRLINGSHIRE.

The mapping of the Aberfoyle slate-bands in the neighbourhood of Garelochhead has been completed by MR. CUNNINGHAM CRAIG, and an examination of certain other portions of Sheet 38 of the one-inch map has been made. A series of specimens for microscopic examination, collected from rocks on the western shore of Loch Lomond, from Luss to Ardlui, has likewise been taken as nearly as possible from the same horizon in the Beinn Ledi grits, between the Aberfoyle slates and the "Green beds." This series has been examined microscopically by MR. TEALL, who finds that the rocks show a well-defined progressive metamorphism from a slightly schistose grit or arkose near Luss to a highly crystalline albite-gneiss near Ardlui. The increase of both dynamo- and thermo-metamorphism can be distinguished, and will be described in detail in the Sheet Memoir.

The existence of "Green beds" near Ardlui has also been established by field-evidence and microscopic examination. These rocks have here attained a very much higher state of alteration than those on the same horizon in other parts of the district embraced in Sheet 38; they are represented by dark green hornblende-schists, containing occasionally "kernels," consisting of chlorite surrounded by clear zones of quartz and albite. Intercalated bands of what were once gritty laminæ containing less of the green material, exist as quartz-epidote schist, with hornblende and felspar, or as albite gneiss with some chlorite and hornblende.

A small mass of plutonic igneous rock north of Inversnaid has been examined. It proves to be a hyperite, consisting of large porphyritic crystals of augite and hypersthene in a holocrystalline matrix composed of bladed plagioclase crystals, hornblende, augite, and biotite, with iron-ores as accessories, and occasionally interstitial micropegmatite.

INVERNESS-SHIRE.

With the exception of certain small patches near Daviot, the area surveyed by MR. HORNE during 1900, forms a belt extending from Farr and Tordarroch in Strath Nairn, eastwards by Ben Nan Cailleach and the Black Water to the neighbourhood of Tomatin. Within this area, the crystalline schists belong to two well-defined groups: (1) Muscovite-biotite gneiss; (2) Granulitic quartzose gneiss and flaggy quartz-biotite granulites. The members of the former group are typically developed in Upper Strathnairn, where they give rise to rough craggy hills between Farr House and Wester Lairgs, on the east side of the Nairn; and between Tordarroch and Loch Duntelchaig on the west. The dominant type is a coarsely-banded flaky gneiss, in which large plates of biotite and muscovite appear, together with

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Mr. Horne. parallel folia of quartz and felspar. This type is usually garnetiferous and often highly corrugated. Small veins and knots of muscovite-pegmatite frequently occur. Again, the quartzofelspathic folia and pegmatites sometimes disappear, and the rock merges into a flaggy biotite-schist. Lenticles of garnetiferous amphibolite are an occasional feature of this group. A traverse from Tordarroch in the valley of the Nairn west to Loch Duntelchaig furnishes good opportunities for studying the characters of this gneiss.

The boundary between the muscovite biotite-gneiss (1) and the quartzose flaggy gneiss (2) is well defined along the eastern margin, on the hills between Farr and Wester Lairks, where it forms a highly sinuous line. The two groups have been affected by a system of inosculating folds, so that long tongues of the one appear in the other. Similar evidence of reduplication by folding is found on the west side, on the hills north-east of Loch Duntelchaig, where a narrow strip of quartzose flagstones intervenes between the margin of the Old Red Sandstone and the muscovite-biotite-gneiss. Eastwards towards Tomatin, the characters of the quartzose biotite-granulites are remarkably uniform. On Ben Nan Cailleach, however, near the watershed between the Nairn and the Findhorn, they become highly quartzose, and weather with a creamy white tint, presenting there the appearance of granulitic quartz-schists.

The southern portion of the Moy granite mass has not yet been mapped, and the description of the small area on the west side, surveyed during 1900, is meanwhile postponed. But close to the granite boundary, and within a distance of two miles from it dykes of microgranite, porphyrite and lamprophyre have been traced, which are probably the apophyses of that plutonic mass.

**Mr. Grant
Wilson.**

MR. J. S. GRANT WILSON continued last year his mapping of the ground to the north of Ben Nevis. Reference has been made in former *Summaries of Progress* to certain dark-grey flaggy mica-schists, and silvery-grey phyllites, and garnetiferous mica-schists displayed in the gorge of the River Spean.* These rocks have now been mapped south-westwards up to the edge of the Ben Nevis granite. As they approach the granite, they gradually pass into dark-grey biotite-schists, and near the contact with the igneous mass become biotite-hornfels rocks. This aureole of progressive metamorphism varies from a quarter of a mile to a mile and a half in breadth. The schists are traversed by a large number of dykes, the rocks composing which vary in type from plutonic through hypabyssal to volcanic rocks. Several broad granite dykes may be noticed at the foot of the Corrie Rois. That the granite is the oldest intrusion is shown by the fact that one of these dykes is intersected by a camptonite dyke with chilled edges, while to the south of the Sgor Pheanais both lamprophyre and porphyrite

* *Summary of Progress* for 1898, p. 45 ; and *Summary of Progress* for 1899, p. 41.

dykes traverse the granite. In the valley to the south of Corrieçoille several altered diorite dykes are cut by lamprophyres. The network of dykes in the schist off the Corrie Rois and Corrie Eoin presents three distinct types, the oldest of which is red and pinkish porphyrite. The dykes of this material are generally of considerable size, one measuring 45 feet in breadth. They have a general trend of N. 30-45 E., and have been traced in some cases for 2,500 yards. They have been determined by MR. TEALL to be hornblende-biotite-porphyrates. They vary from a medium to a coarse grain. Dykes of lamprophyre running more nearly E. and W., cut these porphyrites, and are not so broad as the latter. They are, in general, fine-grained and possess chilled edges. They may be classed as dioritic lamprophyres,* though, in many cases, they have been identified as camptonites. At Tomnafet, Corrie Rois, Lianachan, the valley of the Cour below Coireçoille and at An Gurean, both the porphyrites and lamprophyres are traversed by grey-black hornblende-andesite dykes, similar to the hornblende-andesite rocks described by MR. TEALL† from the summit of Ben Nevis.

The line bounding the Ben Nevis granite has been mapped from the River Lundy to the top of the Aonach an Nid. It is remarkably irregular, the granite sending numerous long apophyses into the surrounding biotite-schist, and including numerous fragments of schist, which decrease in number and size with distance from the margin. A mass of granite, about one square mile in extent, not previously observed, has been mapped between the Coire an Rois and the falls of the Cour, at a distance of three-quarters of a mile to the east of the Ben Nevis "massif," and separated from it by a belt of biotite-schist. The mass is darker in colour than the rock of Ben Nevis and may be classed either as a hornblende-biotite-granite or a quartz-diorite.

Reference may be most conveniently made here to the resumption by MR. GRANT WILSON of the mapping done by him during 1899 on the Moor of Rannoch. Last year he extended the work to the south-west of the Tulla Water. His survey in conjunction with that by MR. KYNASTON on the west side of Loch Laidon has proved that the granite of Ben Cruachan is continuous with that of the Moor of Rannoch.

ARGYLLSHIRE.

The mapping of the Dalradian area, between Glen Orchy and Glen Shira, was continued by MR. KYNASTON from Dalmally, and the unfinished ground near the head of Glen Shira was completed from Inveraray. The remaining portion of the area to the north of Glen Shira was also completed from Dalmally before the close of field-work. The ground surveyed consists

* *Summary of Progress for 1899*, p. 41.

† *British Petrography*, p. 287.

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entirely of rocks belonging to the calcareous-sericite division of the Dalradian schists, together with occasional small sills of hornblende-schist, and affords no fresh facts of any importance beyond those already described in former reports. (See *Summary of Progress* for 1899, p. 43.)

At Kilchrenan MR. KYNASTON was engaged in endeavouring to define the limits of the Loch Awe grits and quartzites. This was done as far as possible; but in many cases it was found quite impracticable to draw any hard-and-fast geological boundary line between these grits, more especially in their finer-grained portions, and the black slates, owing to repeated alternations and interfoldings of the two on a scale too small to be represented on the 6-inch maps. Opportunity was taken to re-examine the various members of the Loch Awe series of sediments and the principal igneous rocks of the district, both later and earlier than the foliation. The results of these observations as far as they concern the Dalradian schists will be here given.

The Boulder Bed.—An excellent exposure of this important stratigraphical horizon in the Dalradian series forms a crag-like feature capping a grass slope a mile and a half W.S.W. from Kilchrenan village. In the burn at the foot of the slope black slates are exposed, but the boulders in the boulder-bed appear to consist almost entirely of quartzite, and sometimes measure at least 2 feet in diameter. They are well rounded, as if water-worn, and comprise rocks of various textures; occasionally, also, a fragment of limestone may be observed. No igneous pebbles have recently been noticed here; but in 1898 Mr. Kynaston found a pebble, which on examination proved to be a fine-grained acid igneous rock, consisting almost entirely of granophyric quartz and felspar. The matrix of the bed consists in the lower portion of black slate, which shows in parts a well-marked banding or lamination, running obliquely to the cleavage. Towards the upper portion of the exposure this matrix becomes gradually quartzose. The presence in the bed of truly igneous pebbles, unlike any rock known in the immediate neighbourhood, indicates that this bed is not due to disruption *in situ*, but was a true conglomerate before any movement such as shearing or crushing took place. From another exposure of the boulder-bed a little farther to the north-east, in the same line of strike, MR. KYNASTON, in company with MR. HILL, collected two or three pebbles of a rock strongly resembling a medium-grained grey granite. A similar boulder-bed, exposed on the shore of Loch Awe, just below the Free Church Manse, Kilchrenan, presents a quartzose matrix, and contains numerous fragments of limestone and black slate. Besides these, two or three small fragments of a pale greenish-grey porphyritic igneous rock were noticed.

A peculiar calcareous conglomerate, exposed 2 miles to the south of Portsonachan, and mapped some years ago by MR. HILL, was re-examined. The matrix is schistose and highly calcareous, the planes of schistosity being vertical or nearly so. The pebbles are not abundant and are usually of small

size, and appear to be restricted to a certain zone or zones. **Mr. Kynaston.** They consist of hard fine-grained quartzite, well rounded, and also some peculiar, elongated and flattened, whitish, felsite-like, fragments. Small fragments of pink felspar and grains of quartz may also be observed. A greenish highly vesicular rock occurs apparently as a thin band in this conglomerate, and a few fragments of a similar rock were also found surrounded by the calcareous matrix. It is probable that this band was folded in with the conglomerate and was fractured during the attendant movements, so that very possibly we have here a case analogous to the "crush-conglomerate" described by MR. HILL from near Inverliever, and possibly also on the same horizon. The quartzite and felsite-like pebbles, however, are undoubtedly original. In some respects the exposure has somewhat the appearance of a calcareous tuff.

Two of the quartzite boulders from the Boulder-Bed when examined in thin slices under the microscope [9059 and 9060] were found by MR. KYNASTON to consist mainly of quartz-grains, mostly well rounded, with a few turbid grains of both striped and unstriped felspar enclosed in a fine-grained usually quartzose matrix, sometimes exceedingly turbid, possibly from decomposed felspar. Some chlorite is also occasionally present. Small zircons are sometimes seen in the quartz grains [9059]. The quartz often shows strain-shadows, but there is scarcely any appearance of schistose structure in the matrix. On the other hand, the matrix of the boulder-bed itself is markedly foliated, and is sometimes seen [9060] to have been forced between the quartz-grains lying at the outer edge of a boulder, though as a rule the margin of each boulder is well defined under the microscope.

If an average quartzite-boulder be compared with the schistose grit, or quartz-schist, which is found close to and apparently above the boulder-bed to the S.W. of Kilchrenan, they will be observed to present on the whole a similar composition, but to show a marked difference in the structure. Whereas there is little, if any, schistosity in the boulders examined, the section of the "Loch Awe grit" [9061] shows much stronger strain-shadows in the quartz grains, a matrix of clear, finely-granulitic quartz, and partial granulitisation of some of the quartz grains, which act as "eyes" in the finer material, as it appears to sweep round them. The rock also contains two felspars, and what appear to represent small drawn-out fragments of black slate. It is not surprising that the harder boulders should have to a great extent escaped the effect of the dynamic forces. Under the influence of pressure they would naturally be more resisting than the softer matrix, which would tend to be squeezed round them. The boulder bed, in short, presents an "augen-structure" on a gigantic scale.

A porphyritic igneous pebble from the exposure of the boulder-bed on the shore below the Free Church Manse, Kilchrenan, shows [9058] phenocrysts of alkali-felspar in a pale brownish, finely-foliated matrix. The felspars are turbid from alteration, but often

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have good outlines, and show Carlsbad twinning. They are often more or less tabular in form, and tend to lie diagonally with regard to the planes of foliation. Partially surrounding the phenocrysts is seen a finely granular mosaic, clearer than the rest of the ground mass, and this together with the felspar-crystal forms well-marked "eyes." Occasionally the feldspars show cross-fracturing. Some ovoid patches of granular quartz are also seen, which may possibly represent original vesicles. The ground mass is strongly foliated, exceedingly fine-grained, and has a somewhat general fibrous appearance, owing apparently to the development of minute flakes of biotite along the foliation planes. The rock was evidently originally a felsite.

The granitic pebbles from the boulder bed, referred to above, are seen under the microscope to consist mainly of a somewhat coarse type of micropegmatite with some plagioclase, and some interstitial chloritic alteration products [9286].

The pale felsite-like fragments from the calcareous pebble-bed, 2 miles S. of Portsonachan, are seen under the microscope [905] to be schistose felsites, which, previously to their foliation, probably had a very compact and flinty texture. They show small felspar phenocrysts, which probably include orthoclase, in a finely-felsitic and somewhat banded matrix, which presents a few small quartz-grains, and is full of irregular opaque specks. Some bands show a finely granular quartz mosaic, and small colourless and pale green needles. The bands are divided by cracks, filled with an opaque material. Flow structure was probably originally present. It cannot be stated for certain that this pebble-bed is on the same horizon as the boulder bed at Kilchrenan. Anyhow, it is interesting to find igneous and foreign pebbles in both. The fragments of vesicular rock occurring in the calcareous conglomerate can scarcely be described as true pebbles, since they were probably derived, as above stated, from an adjacent band of similar rock, which must be classed with the epidiorites.

The following observations were made upon the so-called *Epidiorites* of the neighbourhood of Kilchrenan and Portsonachan. The examples examined may be divided into two fairly distinct classes, though it is probable that intermediate types also occur:—(1) The Dolerite or Diabase type, and (2) the Lavaform type. The former type is common in the area between the main-road, leading from Taycreggan to Glen Nant, and the Pass of Brander. It is also seen on the opposite side of Loch Awe at Bovuy, near Cladich. It occurs in large intrusive sill-like masses, and in a hand-specimen shows a coarse or medium-grained doleritic structure, the colour varying according to the proportion of ferro-magnesian constituents, and the nature and degree of the alteration which the rock has undergone.

A good example of this type occurs in a large mass situated three-quarters of a mile N.N.W. of Ballimore and within half a mile of the Pass of Brander. The rock is decidedly coarse, and shows clear feldspars of elongated columnar habit, unorientated in a dark matrix. A similar rock, but finer grained, occurs a quarter of a mile N.E. of

Ballimore. Under the microscope [9049, 9050] the plagioclase ^{Mr. Kynas-} which is slightly cloudy, is seen to be frequently cracked and ^{ton.} broken, accompanied by slight shifting on either side of the fracture as shown by faulting of the twin lamellæ. The interstices between the felspars are filled almost entirely with secondary minerals—greenish hornblende, chlorite, a pale greenish biotite, epidote, leucoxene, and carbonates. In one slide small patches of a clear mosaic may perhaps represent quartz [9050]. Apatite is accessory, and may occur in relatively large crystals with an elongated columnar habit [9049]. In the coarser and fresher specimen some original augite appears to be present [9049], though in a rather broken-up condition. This type of “epidiorite” was doubtless originally a plagioclase-augite rock closely allied to the dolerites and gabbros. One of the exposures of “epidiorite” examined (a quarter of a mile S.W. of Ballimore), shows large porphyritic felspars, measuring sometimes over 2 inches in length.

The “lavaform” type of “epidiorite” is well seen to the south of Portsonachan, near the central portion of a large mass with a breadth of about four miles, and again to the south-west of Kilchrenan. Two miles S.S.E. of Portsonachan a dark, almost black, schistose porphyritic rock presents under the microscope [9052] phenocrysts of plagioclase, rather turbid, often broken, and occasionally showing partial granulitisation. The phenocrysts have a strong tendency to a similar orientation. Some grains of green fibrous hornblende also occur, and amygdales of epidote, occasionally containing chlorite in addition. The ground-mass is well foliated, and appears to consist to a great extent of minute lath-shaped plagioclase, though it is a good deal obscured by secondary products, and by an opaque material in long streaks and strips, probably consisting to a great extent of disseminated iron-ore. There are also some larger grains of iron-ore, partially replaced by leucoxene. The rock has the appearance of a foliated andesite.

Not far from where this rock occurs, and associated with the same mass, a peculiar band looks at first sight as if composed of fragments of grit set in a greenish matrix. On closer examination, however, the apparently gritty portions are seen to consist of numerous lenticularly-shaped patches of a highly vesicular rock, the vesicles being filled with quartz, and standing out conspicuously from the surface of the mass. These lenticles appear to behave as “eyes” in a fine-grained greenish schistose matrix. A specimen from the vesicular portion was examined under the microscope [9053].

Numerous amygdales, occasionally measuring a quarter of an inch in diameter, but usually smaller, are seen imbedded in a brownish turbid matrix. The amygdales are sometimes almost spherical, though often more or less elongated in a similar direction, so as to appear oval or almond-shaped. They are filled with crystalline quartz, forming usually a rather fine-grained mosaic, which becomes coarser towards its central part. The coarser portions frequently show an undulose extinction

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traversing several contiguous quartz grains, so as to give the appearance of an imperfect spherulitic structure. Some of the amygdales contain calcite in addition to quartz and occasionally some grains of epidote in their marginal portions. The ground-mass is too turbid to allow anything very definite to be made out of it. It seems to consist of felspar microlites in a dark, turbid, brown, undifferentiated (?) matrix; no phenocrysts are seen. The rock has strongly the appearance of a highly vesicular basic lava.

Another well-marked vesicular variety occurs as a band in the calcareous pebble-bed, already described, and also as fragments within it. A section from one of these fragments shows fairly numerous amygdales, filled with calcite, and mostly more or less drawn out. The main mass of the rock consists of larger and smaller lath-shaped plagioclases, unorientated, grains of iron ore, some greenish alteration-products, and interstitial matter. The structure is that of a very fine-grained dolerite or basalt, and probably the original composition had similar affinities. A somewhat similar rock, seen to the S.W. of Kilchrenan, forms hard, roughly spheroidal cores, packed closely together in a dull fine-grained green schist. The slide [9054] is crowded with epidote grains and granular aggregates. The rest of the rock is very turbid from alteration-products, but shows here and there numerous small felspar-laths and an occasional larger porphyritic felspar. The rock is well foliated.

We thus have varieties of the so-called "epidiorites," which in hand specimens and in thin slices under the microscope have every appearance of true lava. Save the lithological characters now described, however, no evidence has been observed in the field that any actual superficial outflows of lava occur among the Dalradian schists. On the contrary, the evidence, as is well known, has always hitherto tended in a contrary direction, and has shown, in most cases conclusively, that the "epidiorites" are really intrusive sill-like masses. Owing to the structural variations, however, which are frequently observable within the limits of a single mass, it may be that many of these constitute complex intrusions, due to successive in-fillings of material, or other causes, such as unequal cooling during movements in the mass; so that fine-grained lava-form types of rock might conceivably occur in the central part of a large mass, where one would otherwise expect to meet with coarsely-crystalline material. From the highly vesicular nature of many of these rocks it would seem not improbable that some of the intrusions did not come far short of the surface, if indeed they did not actually reach it. These lava-form epidiorites may be compared with the vesicular epidiorites reported by MR. SYMES from the Kilmelfort area,* and with similar rocks mapped last year by MR. HILL in the Loch Awe area, near Inverliever.

* *Summary of Progress for 1899*, p. 62. MR. TEALL, in reference to MR. HILL's rocks, has pointed out the resemblance between them and the lavas associated with Radiolarian cherts in the Southern Uplands of Scotland and other localities.

Area between Glen Salach and the Head of Loch Creran, and Mr. Kynaston's Part of Glen Creran.—The mapping of this area is a continuation of the ground surveyed by MR. KYNASTON from Loch Etive side in 1896 and 1897. From the high ground, occupied by the Ben Cruachan granite, to the north-west of Loch Etive, the work was completed down to the shores of Loch Creran, and up to MR. SYMES' ground in Glen Salach. On the north side of Loch Creran and the lower part of Glen Creran the map was now carried up to the ground mapped by MR. GRANT WILSON in 1896. The area now to be reported on consists of quartzites and quartzose beds, phyllites, black schists, and limestones closely resembling those of the Loch Awe area. The more argillaceous and impure calcareous portions of the series have been converted into hornfels by the Cruachan granite. The exact limits of the hornfels area is naturally difficult to decide upon. Intense alteration into hornfels may be noticed at a distance of about a mile from the granite, this change gradually shading off into less altered rocks according as the distance from the granite increases. The alteration is distinctly perceptible along the shore of Loch Creran, near Creagan Ferry, $2\frac{1}{2}$ miles from the granite. This is a continuation of the hornfels zone which has already been studied between Taynuilt and Loch Awe, and described in detail in former reports.* So far as observation has yet gone, no fresh points of petrological importance appear in the extension of the area. The results of field work in connection with the complex marginal area of the granite will be discussed more conveniently in the section dealing with the granites and other intrusive rocks.

Perhaps the most striking feature to be observed in the mapping of considerable portions of this area, is the extraordinary amount of repetition which similar lithological types present. Black or dark slaty schists and quartzose seams are alternately repeated in narrow zones or bands over several miles of ground, in a manner that would completely baffle any attempt at separating the kinds of rock on the map. We have, in fact, a banded series, consisting of repeatedly alternating zones of siliceous and argillaceous material. The rock may be quartzose, banded with black schist or, again, black schist full of quartzose bands, or again, it may be impossible to decide whether the rock is a quartzose black schist or an argillaceous quartzose schist. A hand specimen frequently shows the banding in a very perfect manner; while in the field the bands vary from a few inches up to broader zones quite easy of representation on the maps. This banded series does not owe its essential characters to folding, but to original sedimentary alternations. The finer bands often show intense crumpling, and in one case where fairly coarse quartzose bands alternated with a fine dark schist, the process of the development of "crush-conglomerate" structure was well seen. The rock had undergone shearing along planes running obliquely to the

* *Summary of Progress* for 1897, pp. 88-90; for 1898, pp. 82-91.

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banding, the result being a tendency for the harder band to be drawn out into separate lenticular portions. This banded series is also occasionally seen in the Loch Awe area in certain parts of the Pass of Brander, but it is not there developed over such large areas as near Loch Creran. It is especially well seen on Ben Bhreac, to the east of Glen Salach, and on the hills on the north side of Glen Dubh. The alteration into hornfels tends to accentuate the banding, the hard striped and banded hornfels of this area being exceedingly characteristic.

A well-marked zone of limestone, of the Loch Awe type occurs at the mouth of the River Creran on the north side of the loch, and has been followed for a distance of 2 miles. Above it and on its north-west side is a band of typical black slates, followed by a series of fine-grained quartz-schists and quartzites with their zones of black schist. To the east of the head of the loch the limestone is well exposed in Allt Buidhe, where it is associated with quartzite and black and banded schists changed into hornfels. It is here a highly crystalline bluish-grey or white marble, some portions of it being strongly banded and puckered. The purer bands are more coarsely crystalline, sometimes showing zones of small garnets, while the impure portions consist of dark and pale bands, sometimes greenish, of calc-silicate hornfels, and resemble the banded calcareous series of the Pass of Brander. Intrusions of "epidiorite" are common in certain portions of the area, but are never of large size, frequently, and more commonly, only a few feet in breadth. A decided dyke-like behaviour is sometimes noticeable.

Blackmount.—The Dalradian schists, mapped by MR. KYNASTON from Kingshouse, on the western border of the Moor of Rannoch, are evidently an extension of the similar series (quartzose schists and quartzites), already mapped in Glen Orchy and the south-eastern part of the Blackmount on the one hand, and in Glen Etive on the other hand. In the Kingshouse district, owing to the extensive development of igneous rocks, only insignificant areas of sedimentary material have been mapped. The River Ba, above Ba Bridge, shows a good section of flaggy quartzose schists and quartzites. The rocks usually present different shades of grey, sometimes banded, and sometimes pink, owing to the presence of a considerable proportion of felspar, as is well seen in Allt Coire-an-Easain, a tributary of the Ba, and at Altnafeadh, near the head of Glen Coe. Micaceous schists, sometimes with two micas, are also seen in Allt Coire-an-Easain and above Ba Cottage. Garnetiferous mica-schists, such as these of Glen Etive and the more southern part of the Blackmount, have not so far been observed. Certain breccias in the quartzites will be referred to further on in connection with the volcanic rocks.

Igneous rocks later than the foliation of the schists.—During the early spring of last year, while mapping the Dalradian schists in the neighbourhood of Dalnally, MR. KYNASTON took opportunity of re-examining the remarkable eruptive mass of Glen Orchy. Although these rocks have in former reports been referred to as olivine-monzonites, reasons have been shown in

the paper referred to below for discarding the term in favour of Mr. Kynaston.^{ton.} a new one, and the term Kentallenite has been proposed, the rock from Kentallen,* near Ballachulish, being taken as the type. A detailed examination of the section exposed in Allt Broighleachan showed the lowest portion of the mass to consist of a band of coarse *hornblende-picrite*. At its lower margin the picrite passes into a marginal modification resembling a basic lamprophyre. At the upper margin it passes somewhat abruptly into the kentallenite in such a way that no sharp line of demarcation can be traced, nor any well-marked transitional phase. The lower portions of the kentallenite are, however, more basic than the normal type, showing very little felspar, with a high proportion of augite and olivine, and a very coarse texture. Followed upwards, in the burn-section, this type passes into the normal rock, which again shades into a less basic and slightly finer-grained variety towards the upper margin of the mass. On the whole, then, the variation is well marked and of a vertical character. The upper portions of the intrusion, as in the Carboniferous picrite of Blackburn, Linlithgowshire, are the more acid, while the more basic minerals have tended to concentrate in the lower part, and have consolidated as a layer of ultra-basic rock.

Under the microscope the picrite is seen [9009] to consist essentially of olivine, hornblende, augite, and biotite. Only a very minute and insignificant quantity of felspar is occasionally to be seen interstitially. Magnetite is accessory, but chiefly occurs in connection with the alteration of the olivine. The olivine is fairly plentiful in rounded grains. The hornblende varies from brown to greenish, or is sometimes almost colourless, the various gradations of colour being often visible in the same individual; it occurs in large irregular poikilitic plates, which enclose both the olivine and augite. The pleochroism is not markedly strong. Occasionally this mineral seems to form a marginal outgrowth from the augite, and may perhaps be partially formed at its expense. The augite is colourless, or almost so, and seldom shows crystal form. The biotite is of a deep orange-brown variety, and strongly dichroic. It is of later formation than the hornblende. Felspar is rare, but occasionally occurs in small interstitial patches, without any signs of twinning. This is somewhat suggestive of orthoclase, since we know that the plagioclase of the closely associated kentallenite crystallised out before the biotite, and the orthoclase last of all interstitially. The order of consolidation of the minerals in the picrite is—olivine, augite, hornblende, biotite, felspar. Towards its lower margin the picrite becomes finer-grained and shows affinities to the basic lamprophyres, while vein-like streaks and patches rich in felspar are not uncommon. The microscope shows [9007, 9008] this marginal portion of the mass to be rich in hornblende,

* Described by MR. TEALL, *Ann. Rep. Geol. Survey*, for 1896, p. 22. *Summary of Progress* for 1899, p. 57. See also a paper by MR. J. B. HILL and MR. KYNASTON, *Quart. Journ. Geol. Soc.*, vol. lvi., pp. 534, 535, etc., and pls. xxix., fig. 2., and xxx., fig. 1.

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while the proportion of olivine and augite has considerably diminished. The hornblende is green and greenish brown, and occurs in idiomorphic prisms, frequently giving a lath-shaped section, as in camptonite. The augite is considerably altered and sometimes pseudomorphosed. The olivine is represented by pseudomorphs of colourless amphibole needles and magnetite. Secondary green hornblende-needles often form a border surrounding the pseudomorphs. Some biotite is present in small flakes, and sometimes small grains of sphene [9008]. Felspar is fairly plentiful, and resembles that of the lamprophyres, occurring as small plagioclase crystals with good idiomorphism. A small quantity of interstitial quartz is present. Patches rich in felspar are somewhat coarser than the surrounding rock, but graduate imperceptibly into it. They consist of idiomorphic plagioclase and micropegmatite.

Passing now to the upper part of the picrite mass we find, as we approach the kentallenite, that the rock becomes slightly coarser, and that the microscope shows [9010] the hornblende to have diminished, while the augite has increased, the hornblende usually occurring about the margins of the augites. The proportion of felspar does not appear to have perceptibly increased. The next phase in the mass that is exposed is a basic form of the kentallenite, showing a low proportion of the felspars, and occasionally a small quantity of pale green hornblende [9011]. In the typical kentallenite the hornblende has entirely disappeared, and the biotite is of a browner colour, and does not show the rich orange tinge characteristic of that mineral in the picrite. The upper margin of the kentallenite does not assume a particularly fine-grained aspect, but seems to show an approach to lamprophyre [9015]. It is too decomposed for satisfactory description. The variety, which shows well formed olivines and augites in a ground-mass of biotite, plagioclase and alkali-felspar, is not a marginal modification, but occurs as roughly spheroidal masses, up to 2 feet or more in diameter, enclosed within the normal type. In one place a narrow vein was seen of very coarse white felspar and large biotite plates, doubtless analogous to the pegmatite veins so common in certain granites, and consisting, as is also the case in pegmatite, of those constituents of the parent rock which were the last to crystallise out from the intruded magma. Some interesting inclusions were observed in the picrite. Ignoring occasional pieces of quartzite, they are of two kinds:—(1) mushroom-shaped inclusions, 6 inches or so in diameter, of fine-grained kentallenite, and (2) nodular lumps, a few inches in diameter, of a fine-grained dark greenish rock, resembling certain lamprophyres, and showing conspicuous phenocrysts of hornblende. The rock of the mushroom-shaped inclusions consists [9013] of relatively large, idiomorphic, zoned augite and olivine in a fine-grained ground-mass of felspar, with elongated, irregular, strips of biotite, and small pyroxene granules. It resembles the rock of the spheroidal masses in the kentallenite. The other inclusions consist of large

brown and greenish hornblendes, resembling the hornblende of the picrite, in a micro-crystalline and rather peculiar ground mass. It is not uniform in composition; some parts, though rather obscured by decomposition, appear to consist of plagioclase and orthoclase with some scattered hornblende needles, while other parts are rich in alkali-felspar, and crowded with small colourless grains and crystals of pyroxene. Some sphene, apatite, and magnetite are also present. It is not easy to explain these inclusions; they may, perhaps, represent magmatic concretions or consolidations of an earlier phase. That they are intimately and genetically connected with the mass in which they are found, their petrological affinities sufficiently show. They afford, moreover, an interesting link completing the chain of evidence which binds together the picrites, kentallenites and lamprophyres.

It may further be stated in this connection that while working in Glen Shira in September, MR. KYNASTON revisited the kentallenite intrusions, mapped by MR. HILL, of the Brannie and Allt-ant-Sithein burns. That of the Brannie burn, like the Glen Orchy mass, was found to be associated with a coarse dark-greenish picrite, which occurs at the lower margin of the kentallenite in the burn-section, and apparently forms a band about 15 yards in breadth. There seems to be no great amount of variation in these Glen Shira kentallenites. What there is appears to be mainly textural, the rock becoming finer-grained at the margins, and finer and coarser varieties occasionally seem to alternate in successive bands.

The recognition of picrite in intimate association with the Argyllshire kentallenites is of special interest, inasmuch as it proves that ultra-basic rocks must be included as an additional group in the large and varied series of associated intrusive rocks, which form so marked a feature in the geological structure of the district.

Brief reference may here be made to certain sills of augite-diorite on Meall na Laoigh, between Glen Orchy and the head of Glen Stræ, a specimen from one of which has already been described.* Fresh observations have brought out some interesting points bearing on the nature of the intrusions and the relationships of some of the rocks in the same area. They are composite sill-like intrusions, each exhibiting precisely similar features. At the margin, a fine-grained rock, resembling in hand-specimen a basalt, shows phenocrysts of augite and olivine. This passes into the main mass of the intrusion, an augite-diorite, consisting of idiomorphic augite, two feldspars, and biotite, with an occasional accessory pseudomorph after olivine, and some sphene and magnetite [8945]. The central portion of each intrusion, however, is a rock of more acid appearance, consisting essentially of elongated prisms of greenish-brown hornblende and alkali-felspar, with accessory plagioclase. The alkali-felspar

* See *Summary of Progress* for 1899, p. 60; *Quart. Journ. Geol. Soc.*, vol. lvi., p. 546.

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consists of a granular aggregate, forming, as it were, a ground mass, in which the idiomorphic hornblendes lie embedded [8946]. A similar structure is seen in some of the Cornish minettes described by Collins,* in which the matrix that encloses the other constituents is a coarse-grained aggregate of unstriated felspar. The Meall an Laoigh rock may be classed as vogesite, hornblende being the predominant ferro-magnesian mineral. Sphene and apatite are accessory. The boundary between this rock and the augite-diorite is sometimes, but not always, sharp. The vogesite appears to be merely a slightly later intrusion from the same magma. It has no chilled edge, so cannot be regarded as a later dyke cutting the augite-diorite; but it is often rather intermingled with the latter rock, in irregular veins and strings, as if intruded before the diorite's complete consolidation. And further, the augite phenocrysts, so characteristic of the diorite, are also found sparingly, as hornblendic pseudomorphs, in the more acid rock.

The basic rock, forming the marginal portion of these sills, shows under the microscope [8944] phenocrysts of idiomorphic augite and pseudomorphs after olivine, in a microcrystalline ground-mass consisting of lath-shaped plagioclase, small greenish (? pyroxene) granules, the interstitial matter possibly including some alkali-felspar and accessory magnetite. The pseudomorphs after olivine illustrate the amphibole type of alteration. They consist of a fine felted aggregate of colourless amphibole-needles, sometimes associated with some iron-ore, and are usually surrounded by a border of green fibrous amphibole, often mixed with colourless needles.

A similar alteration-product after olivine is seen at the margin of the Glen Orchy picrite (see *ante* p. 37), and is probably similar to the "pilite" of Becke.† This marginal phase has affinities with certain basic lamprophyres and with the variety of kentallenite which occurs as inclusions in the picrite already described. This association of rock types observed in these Meall an Laoigh sills furnishes another example of the close genetic relationships between the augite-diorites and the lamprophyres of this area. In its general features the differentiation observable in these intrusions is closely paralleled by several of the intrusions of the Ben Bhuidhe area, and especially by the dioritic intrusion of Clachan Hill, which varies from augite-diorite, occasionally showing accessory olivine-grains, and in part closely resembling a basic lamprophyre, to a dioritic rock of the camptonite type.‡

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The field-work carried on by MR. HILL in the summer lay in the district around Kilmartin, to the south-west of the Loch Awe basin. The whole of the members of the "Loch Awe

* See Teall, *British Petrography*, pp. 355-357.

† See Teall *British Petrography*, p. 86, and Rosenbusch and Iddings, *Microscopic Physiography*, p. 217 and pl. xix., fig. 2.

‡ These kentallenites and augite-diorites are most probably of the same geological age as the Ben Cruachan granite, in view of the close relationships that have been shown to exist between them.

series" are here developed, consisting of grits, slates, and lime- Mr. J. B. Hill.
stones, with which are associated enormous masses of igneous material of Dalradian age, ranging in composition from intermediate to basic, while porphyrite dykes of later date are met with, probably belonging to the period of the Lower Old Red Sandstone. Further a series of Tertiary dykes of basaltic type traverses the county in a north-westerly direction at right angles, to the strike both of the sedimentary groups and of the igneous rocks associated with them.

The "Loch Awe series" having been described in previous Reports calls for no further description here. The limestone forms its base, and the grits and quartzites are its upper members. The different groups of the series often shade laterally into one another. The limestone especially is often most variable in character. From its normal condition of a crystalline blue limestone it passes to a calcareous grit on the one hand and a calcareous slate on the other. In its gritty condition, which is very common in this area, the limestone matrix is full of grains of blue quartz and felspar, sometimes an inch in diameter.

The rocks are everywhere thrown into isoclinal folds, which are steep, often even vertical. The bedding is, on the whole, not far from the horizontal, with foliation nearly vertical. The members of the Loch Awe series lie here in a gentle trough of the Ardrishaig series. The metamorphism is of a feeble kind, some zones having practically escaped alteration.

The igneous rocks of epidiorite type are extraordinarily abundant. They can be traced as a belt five miles broad, amongst which discontinuous strips of sedimentary rocks are enclosed, while fringing this mass the igneous material so diminishes as to present the normal condition of large sills enclosed in the sedimentary formations. This remarkably extensive tract, although composed of material that may generally be described as epidiorite, embraces rocks so little altered that their original igneous structures remain conspicuous. They vary in composition from basic to intermediate, the dominant minerals being hornblende and felspar, with chlorite, epidote, calcite, quartz, and iron ores as accessories. Every gradation in structure may be followed from a coarse gabbro-like type to the finest schist. The most prevalent variety is a felspar-hornblende-schist, with porphyritic feldspars scattered in it, commonly associated with bands of very fine chlorite-schist, in which the porphyritic feldspars are equally abundant. Rapid alternations occur of zones, in which the porphyritic feldspar varies in amount, and is sometimes altogether absent. Similarly the ground-mass varies both in texture and composition. These differences in structure and composition, being often sharply marked off from each other, produce banded structures in the rock, while some of the chloritic bands in which porphyritic feldspar is absent cannot readily be distinguished from sedimentary material. The porphyritic feldspars occur in idiomorphic crystals, but they are often broken across and have rounded outlines; yet, not-

Mr. J. B. Hill, withstanding the highly sheared condition of the matrix, they have on the whole suffered but little crushing. They are frequently half an inch long, while occasionally crystals 2 inches in size have been observed. In some zones the porphyritic feldspars are so packed together that the ground-mass is almost excluded. Although some portions of the mass show the hornblende as porphyritic, this type is not common, the feldspar being usually the porphyritic constituent. While as a whole the rock is fairly fresh, considerable masses present a highly decomposed condition in which the hornblende is entirely broken down, though tiny feldspars often remain. In this state the rock often becomes strongly calcareous from the breaking down of the lime-bearing hornblende and feldspar, and partly doubtless from the decomposition of the limestones with which they are associated. The green calcareous schists thus produced are often difficult to separate from rocks of similar character which are undoubtedly of sedimentary origin. Many of those rocks, both in the most and the least altered state, possess a vesicular structure, the vesicles being sometimes filled with calcite, more rarely with blue quartz, or remaining as partially-filled drusy cavities. Where the igneous mass is least altered the porphyritic feldspars of idiomorphic character have suffered little or no alteration, hornblende is absent, and the structure of the rock is truly igneous, consisting of bands of more or less altered andesites divided by more sheared portions which may represent flow structure. MR. TEALL has pointed out the resemblance of these unaltered rocks to the volcanic accompaniments of the Lower Silurian Radiolarian cherts in the south of Scotland and elsewhere. They can be traced into normal epidiorites of Dalradian type, and, as already remarked with regard to examples in MR. KYNASTON'S ground, the field-evidence usually favours their intrusive origin. No example has here been found of the peculiar sack-like or pillow-shaped structure, so characteristic of the lavas associated with the Radiolarian cherts. Nor has any trace been found of such cherts, or of volcanic tuffs or agglomerates. Epidote, is common to all the different types of the epidiorite, but the occasional occurrence of albite in tiny clusters, somewhat similar to those in the mica-schists of Cowal, is of interest.

The smaller sills that lie beyond the boundaries of the large mass need no special remark, as they present no characters which are not represented within that mass. In connection with the little-altered andesitic varieties, reference may here be made to rocks of similar type, which in 1893 were mapped by MR. HILL, between Kilchrenan and the Pass of Brander, and of which the original igneous character is not much altered. In these rocks hornblende and chlorite, generally such conspicuous minerals in the epidiorite group, are absent, the ferro-magnesian minerals being represented by green biotite, while in one instance white mica also occurred. MR. HILL'S former work in the "Loch Awe series" proved that the normal crystalline schists of the Highlands pass gradually in this part of Argyllshire by phases of diminish-

ing metamorphism into sedimentary strata little removed from normal Palæozoic formations. His recent observations show that in the same region these rocks include a large mass of truly igneous material which has undergone so little alteration that its original crystalline characters can readily be determined

The isoclinal type of plication, so prevalent over the district, has sometimes been developed to such an extent that the junction-line of two rocks is now marked by a banded zone, in which the alternations are so narrow that they range from a foot to as little as an inch in thickness. While in some cases the process has ended here, in others it has been carried further, and the sharply-packed folded bands have been divided by shear planes that sever the continuity of the limbs, the fragments thus produced having been more or less isolated, until at last, by the rolling out of these fragments, pseudo-conglomerates or crush-conglomerates have been developed. These structures have been observed in the limestone, the quartzites, and the epidiorites, but they are most conspicuously developed where the limestone and epidiorite are in juxtaposition. Sections are rarely seen in which the various stages of this process can be continuously traced from the beginning to the end. Consequently, structures which have originated in earth movements may sometimes be confounded with phases of contemporaneous deposit, such as the great boulder-bed of the Central Highlands already referred to.

As the principal topographical features of the region correspond both with the strike of the beds and the axes of folding, deep transverse sections showing clearly the passage of one rock into another are far from plentiful. The ground near the upper end of Loch Craignish, however, is divided by valleys which cross the lines of ridge. Isolated platforms have thus been blocked out, so to speak, from the rest of the country, and as these transverse valleys have had their trend determined by lines of fault, they display steep escarpments in which sections are laid open across the strike and the axes of plication. While the folding and foliation are everywhere seen to be dipping at high angles, the escarpment-faces show that the strata, although somewhat undulating, are on the whole practically horizontal, a structure exactly the reverse of what the surface-features would suggest. Examination shows that a mass of gritty limestone is overlain by an epidiorite sill, of which probably only the lower portions are to be seen. The visible part of this sill is of the vesicular type, and is probably an extension of the great sill already alluded to. The junction of the igneous sheet with the limestone is intricately folded, strips of epidiorite from a few inches to a foot or more in thickness being packed together at a high angle in a limestone matrix. Large blocks may be seen in process of division by the shearing movements which have succeeded the folding. Amongst the folded limbs boulder-like blocks occur completely isolated. These blocks are usually of epidiorite, but some of limestone may also be seen. The limestone, however, seems generally to have played the part of a plastic body, accommodating itself as a matrix to the folded and

Mr. J. B. Hill, isolated fragments of epidiorite, between which it has been squeezed. A bed of this fragmentary nature, varying from two to six yards in thickness, rests on the limestone more or less horizontally. In this bed the long edges of the folded limbs and detached fragments are in alignment with the strike of the foliation and of the axes of the folding, so that a cross section displays a series of closely-packed lenticles standing on edge, bound together in a limestone matrix. The junction of this composite mass with the limestone below is not sharp; igneous blocks, some of which are well rounded, being included in the limestone for some distance, while near the junction of the limestone solid cores of epidiorite occur, two or three feet across, which have not been broken down into boulder-like masses. The blocks of epidiorite, a foot or less in length, are often perfectly rounded and lie in places at some distance from the nearest visible epidiorite. An examination of them shows that they belong to the vesicular type of epidiorite which reposes on the limestone, but many of them are fresher and more compact, with no trace of foliation. Blocks of the more decomposing type, which is the prevalent feature of the parent mass, do, however, occur. There seems on the whole to be ground for assuming that these "crush-conglomerates" are older than the foliation, and that the boulder-like blocks largely escaped deformation owing to the relative plasticity of the limestone in which they are interned. Boulders of grit may also be seen in the limestone, evidently derived from a grit band which is sometimes found to abut against that mass.

The district presents many examples of this peculiar structure at the junction of the epidiorites with limestone. But these phenomena are also observed amongst other rocks; they have been seen in the quartzites and within the epidiorites themselves, although in these latter cases, owing to the comparatively homogeneous nature of the material, they are not so conspicuous. Isolated blocks of quartzite have often been observed in a matrix of the same material, likewise boulders of slate and limestone have been met with enclosed in limestone. For want of a better explanation, they have been assumed to be related to the Highland boulder-bed, but there can be little doubt that in this part of Argyllshire they are more often crush-conglomerates.

The crush-conglomerates of Cornwall were described in the last *Summary of Progress*, and their relation to the composite nature of the beds in which they occur was pointed out. Bands of alternating material of different kinds offer a resistance to stress less uniform than that shown by more or less homogeneous masses. In Argyllshire crush-conglomerates have most frequently been formed near the junction of rocks totally dissimilar in character, the junction of epidiorite and limestone being especially favourable for their production. The limestone associated with these conglomerates is generally of a gritty nature, which may have favoured differential movements within its mass.

The mapping of that northern part of Argyllshire which forms the district of Ardgour, on the west side of the upper section of Linnhe Loch, was resumed last year by MR. GRANT WILSON. In this district a foliated epidiorite was encountered in the year 1898 at the foot of Glen Scaddle.* The field-work during the past season has shown that the area occupied by this igneous rock and its accompanying margin of acid gneiss is much larger than was at first anticipated, since it extends as far south as Sgùrr nah-Eanchainne, above Glen Gour. The hill-streams on both sides of Glen Scaddle afford clear and continuous rock-sections, and a large number of these have been examined. In the following table the various igneous rocks, which form the Glen Scaddle network, are arranged in their chronological order of intrusion, the oldest being placed at the beginning and the youngest at the end:—

Foliated Rocks.	(1)	Epidiorite.	
	(2)	Granulitic gneiss.	
	(3)	Diorite dykes, cutting granulitic gneiss and flagstones.	
	(4)	Grey basic dykes, now represented by Hornblende-biotite-schist	Cutting epidiorite, granulitic gneiss, and flagstones.
	(5)	Granulitic gneiss and Aplite (porphyrite) dykes	Cutting epidiorite, granulitic gneiss, diorite dykes, flagstones, and grey basic dykes.
Unfoliated Rocks.	(6)	Granite dykes	Cutting diorite dykes, epidiorite sills, and flagstones.
	(7)	Dolerite dykes Basalt dykes	Cutting all the other members of the series.

(1.) A microscopical description of the epidiorite has already been given,† together with a description of the section exposed along the course of the River Scaddle. The epidiorite continues to present the same general features as in the portion previously mapped, save that towards its centre the rock becomes less foliated, is much coarser, and contains hornblende crystals sometimes half an inch long. At many points not far from its margin the uniform grey colour of the rock changes to a dull red tint, owing to the pink hue of the felspar. As the ground is almost entirely free from superficial deposits, the outline of the epidiorite has been accurately traced for a distance of seven miles. It is remarkably sinuous, as the eruptive mass projects in tongues into the surrounding rocks.

(2.) Between Keil and Craighheitheachain the epidiorite is surrounded by a zone of granulitic gneiss,‡ which varies in breadth from 10 yards to half-a-mile. The line of junction between the two rocks is everywhere sharp, contrasting in this respect with the line between this gneiss and the flagstones, which is indefinite, and much more complicated. For some distance beyond the zone of acid rock the flagstones are often traversed by numerous small dykes of acid granulitic gneiss.

* *Summary of Progress* for 1898, p. 40. † *Ibid.* ‡ *Ibid.*, p. 41.

Mr. Grant
Wilson.

(3.) In Glen Cona the river-section for a distance of half-a mile below the Keeper's house, exposes numerous foliated diorite dykes from two to thirty feet broad which traverse the flagstones. Some of these in turn are cut by small dykes of granulitic gneiss and veins of aplite. To the south-east of Glen Scaddle several broad diorite dykes cut both the acid gneiss and the flagstones.

(4.) Eleven foliated grey basic dykes,* now represented by hornblende-biotite-schists, were mapped last year on the southern slopes of Glen Scaddle. They intersect both the epidiorite and the granulitic gneiss, while two in Glen Cona traverse the flagstones.

(5.) On the south side of Glen Scaddle the epidiorite is cut by a large number of dykes and veins of foliated granulitic gneiss and aplite (porphyrite)† from an inch up to twenty yards in breadth. Similar dykes have also been mapped to the south-east of Corrlarach in Glen Cona intersecting the flagstones.

(6.) On the east side of the Gearr Lechdann in Glen Cona a rocky ravine in the flagstones exposes dykes of foliated diorite which are cut by small dykes of unfoliated pink granite. On the top of the hill above the ravine a large diorite dyke, which extends for some distance, is also traversed by no less than three dykes of unfoliated granite.

(7.) No further remark is called for in regard to the basic dykes of probably Tertiary age.

The granulitic micaceous flagstones ("moine schists") in the ground surveyed last year on the north side of Glen Cona are of the usual type, and call for no special mention. They are traversed by sills of foliated epidiorite and dykes of pink unfoliated granite. On the hillside above Corrlarach, and also in the river to the south-east of it pegmatite veins occur, apparently an eastward extension of the large veins which traverse the flagstones to the north-west of Glen Cona.

Mr. R. G.
Symes.

The tract of Dalradian rocks surveyed last year by MR. R. G. SYMES embraced the islands of Lunga, Luing, Torsay, and Shuna along the west coast of Argyllshire. The following account of the work has been drawn up by MR. PEACH, who supervised the progress of the mapping.

Lunga, the most westerly of these islands, as was long ago shown by MACCULLOCH, is almost entirely built up of massive quartzite and siliceous schists, presumably the northern extension of the Jura and Scarba rocks. Two outcrops of impure slate of no economic value occur on the east side of the island, near the solitary dwelling-house, where they are involved with the quartzite in the system of isoclinal folds into which the rocks of the whole island have been thrown. The long axes of the folds and the strike of the strata trend nearly north and south, while all the beds appear to dip at high angles towards the east. Trials have been made to work the slate, but without success.

* *Summary of Progress* for 1898, p. 41. † *Ibid.*

Luing, the largest of these islands, lies to the east of Lunga, ^{Mr. R. G. Syme.} and is only separated from the island of Seil on the north side by the narrow Cuan Sound. The rocks of Luing are, therefore, a continuation of those of Seil, and are arranged in the same system of isoclinal folds so well seen in the slate quarries of Easdale and elsewhere in Seil. The same slate and limestone bands also occur on different outcrops over an area of country more than two miles wide measured across the strike. The greater part of Luing is, therefore, built up of slates, phyllites, and limestone bands. Occasional bands of quartzite and siliceous schist occur in the middle of the island, and a massive sheet or sheets of epidiorite are folded with the limestone and phyllites towards the east of the island. This igneous intercalation is probably the continuation, through the island of Torsay, of the sheet which occupies the centre of a compound syncline on the south-east of Seil. If this be the case, then the structure of Lunga is also that of a compound syncline. In the north of the island the strike of the beds is nearly N.N.E. and S.S.W., but in the southern half nearly N. and S., while their general dip throughout is towards the east.

The equivalents of the rocks of Shuna on the mainland appear to be a portion of the Ardrishaig phyllite group, the Black slate group, and the Loch Awe limestone. The workable slates of this island as well as Seil probably belong to the Black slate or Black schist group.

Torsay and Torsay Beag are only periodically separate islands, for the channel between them and Lunga is laid bare at low water. The same rocks and structures that occur on the west of that island are continued through them. The larger of the two islets is made up chiefly of slates and phyllites that form the eastern limit of the compound syncline just referred to, while Torsay Beag, lying in the centre of the trough, is formed of portions of the great epidiorite sheet. Thin epidiorite sills, however, occur folded with the slates and phyllites on the eastern shore of Torsay. No slates have been worked on these islands.

Shuna lies to the east of Lunga, being separated from it by Shuna Sound, which is more than half a mile wide. Nearly all the western side of the island is composed of calc-sericite schist and impure limestone bands. From Shuna Point, its extreme southern headland, the western shore for some distance northwards is occupied by a band of massive quartzite, which at a point south of Shuna Cottage is truncated by an east-west fault, with a downthrow to the south. The remaining part of the island is made up of silvery grey phyllites and mica-schists. The strike of the beds is N. and S., and their dip persistently eastwards, which causes its calcareous sericites to seem to underlie the grey phyllites, but owing to isoclinal folding this appearance may be deceptive. Some of the impure limestones have been extensively burned; but at present a better limestone is imported from Lismore. The rocks of Shuna probably belong to the Ardrishaig phyllite series of the mainland.

Mr. R. G.
Symes.

In addition to the granite masses that occur in the neighbourhood of Kilmelfort,* numerous bosses of granite have recently been found on the mass of high ground to the south of Glenmore. The granite of these masses is similar in character to those already reported on, and the alteration round about them identical. The granite is fine-grained with prominent biotite, and, as MR. TEALL has ascertained, with augite as a constant constituent. Within the contact zone of this rock the ordinary phyllites are converted into biotite-hornfels, while in the impure calcareous rocks calc-silicates have been developed, and the rocks become calc-silicate-hornfels, in some cases pyroxene-epidote hornfels. Near its contact with the schist the granite passes insensibly into a rock with a felsitic ground-mass. From the mode of occurrence of the granite masses in the area south and west of Kilmelfort, there is reason to believe that they form part of one great intrusion which has lifted up the schists and altered them, and that the separate areas now exposed are due to unequal denudation. Further, the distribution of hornfels in places where there is no visible granite suggests that granite may be concealed beneath, so that all the granite bosses in the Kilmelfort may actually be connected below ground. In the *Summary* for 1899 it was suggested that these bosses had probably all been derived from the same magma. When the fact is considered that the granite edges and apophyses pass insensibly into porphyrites which sometimes exhibit flow structures, there is evidence in favour of the opinion that the granites may have been connected with the later and more acid phases of the Lorne volcanic episode (Lower Old Red Sandstone), and that the volcanic rocks of that region ascended from the same underground magma as the granites and porphyrites now referred to. If this view be eventually established, it will form another interesting addition to the examples of granite of Old Red Sandstone age, and to the association of granite with abundant volcanic manifestations.

Mr Peach
and Mr.
Wilkinson.

Island of Jura.—The survey of this island was finished last year. In order to ensure its completion, MR. PEACH took a portion of the ground on the west side of the extreme north end of the island, and he has furnished the following abstract of his mapping:—The same rocks which constitute the rest of the island to the south are continued to the northern extremity. They consist of partially granulitised quartzites and quartz-schists, which are sometimes pebbly and even conglomeratic, and phyllites, some of which merge into the quartz-schists on one side and into pure phyllites on the other. In places they are calcareous or dolomitic, and are traversed along the bedding-planes with worm casts identical in character with the so-called "Fucoids" found in beds on the shores of Islay and in the Cambrian rocks of the North-West Highlands. The general assemblage of these Jura rocks resembles in every respect that met with in Islay, from the basement quartzite up to and including part of the so-called "Fucoid-beds."

* *Summary of Progress* for 1899, p. 63

Over the whole area mapped the rocks dip persistently towards the S.E. and E.S.E., at angles varying from 20° to 50° , so as to give rise to the deceptive appearance of an upward succession from west to east; but on close examination they are seen to be folded upon themselves in sharp isoclinal folds, the axes of which have a north-easterly and south-westerly trend. Several distinct lines of actual disruption or thrust planes with nearly the same inclination as the strata, are well exposed along the wave-swept coast, while small reversed faults may be observed in great numbers. The phenomenon of "staving" of the beds is also very conspicuous, especially among the overriding masses that have been pushed along the thrust planes. The band of "pipe rock," first observed by the Director-General on the shore of Glendebadel Bay,* was traced inland across a peninsula to Glengarrisdale Bay, where, in addition to the ordinary "pipes," trumpet-shaped pipes were found to occur in it. The "pipe-rock" band was also found and traced along several outcrops on various strikes. From the character of this band and its relations to the rest of the quartzite it cannot correspond to the "pipe-rock" zone found in Islay, but must be an integral portion of the basement quartzite.

Mr. Peach
and Mr.
Wilkinson.

The fucoidal calcareous phyllites are best seen on the shore at Bagh Uamh nan Gall, near the cave at the eastern angle of the bay, and on the flat shore near the mouth of Allt Loch na Conaire, where the matted sandy worm-casts weather out on the surface of the schist in fine relief. This bed was also found on other outcrops further to the east. A calcareous band, in which no worm-casts were observed, occurs near the outcrop of "pipe-rock" in Glendebadel Bay, and probably supplies the calcareous matter for the stalactites found in a cave near its outcrop. A band of conglomerate occurs on the shore near the outcrop of this band of "pipe-rock" in Glengarrisdale Bay, the matrix of which is quartzite. It contains pebbles of granite like those in the quartzite conglomerates and the Port Arkaig conglomerate in Islay. This band probably corresponds to the conglomerate found in Islay near the top of the basement quartzite.

From these facts it may be inferred, with strong probability, that this part of Jura is built up of the basement quartzite, and the lower part of the "fucoid-beds" of Islay, spread out by constantly repeated isoclinal folds, thrust planes, and reversed faults.

On the east of the island at Barnhill and Kinnachdrach, and for about a mile north as far as Port an Draighann, schists with quartzose and calcareous beds and some few small beds of blue limestone have been mapped by MR. S. B. WILKINSON. These strata are similar to the group of schists met with further south at Ardménish and Ardfin, and also in the island of Islay. Due east of Barnhill House the strata become conglomeratic; their matrix consists of highly calcareous material, enclosing pebbles and lenticular masses of

* *Summary of Progress* for 1898, p. 68.

Mr. Peach
and Mr.
Wilkinson.

various rocks. These enclosures consist of blue, violet, and white quartz, limestone, felspar, grit, and possibly granite. Some of the lenticular blocks are a foot long. Underneath these fragmentary beds lie flaggy quartzose grits and highly-puckered black slates with small quartzite bands.

From the nature of the materials, the constant alternations of the beds, and the continuous easterly dip, the western and northern sides of the north end of Jura are remarkably bold, rising abruptly by a succession of cliffs to heights of from 600 to 1,100 feet within a mile or so of the shore. The hills and cliffs are further trenched by glens and steep-walled gashes, along which the streams make their way to the sea. Almost every one of these trenches, as well as the indentations on the western shore, corresponds to a weathered-out dyke of igneous rock or shattered fault-line.

The oldest of the intrusive igneous rocks are basic dykes now in the condition of epidiorites, many of which have been traced throughout the ground surveyed last year. For the most part they have a general N. and S. course, but constantly give off branches which may reunite with the parent dyke or cross obliquely from one dyke to another. One example was traced across the area at nearly right angles to the general trend. These epidiorite dykes occupy more or less vertical fissures which must have been formed after the corrugation and foliation of the quartzite. Their material is fine-grained, more or less foliated near the margin and coarser and unfoliated in the interior, but the felspars are now represented by saussuritic aggregates, and from their light glaucous green colour it may be inferred that they probably contain a considerable amount of chlorite. The foliation near their edges is evidently due to motion after consolidation.

This ancient system of dykes is cut by sills and dykes of unfoliated lamprophyre which may be seen on the shores and in the cliffs overhanging Glentrosdale Bay and Bàgh Uamh Mòhr, Beinn nan Capull. Both of these series of igneous rocks are in turn cut by dykes of olivine-basalt and dolerite, which occur in considerable numbers, and have a trend from E.N.E. to W.S.W. Two large dolerite dykes are traceable right across the island from shore to shore. The age of the epidiorites is unknown, though it must be later than the general plication and foliation of the quartzites and schists. The lamprophyres may be connected with the protrusion of the great granite masses on the opposite mainland, and may thus belong to the time of the Lower Old Red Sandstone, while the basalts and dolerites no doubt form part of the abundant records of Tertiary volcanic action in the West of Scotland.

Silurian.**WICKLOW AND WEXFORD.**

The revision of the Silurian tracts of Counties Wicklow and Wexford, which was resumed last year by MESSRS. EGAN and McHENRY, was completed before the end of the working season. MR. EGAN'S illness prevented him from continuing in the field after the beginning, and his subsequent death has deprived the Survey of the report which he would have furnished of the recent mapping. The following notes are condensed from the details supplied by MR. McHENRY.

Mr. Egan
and Mr.
McHenry.

The conclusions formed in previous years as to the nature of the so-called lavas and tuffs in this region were generally confirmed by the revision of the remaining portions of the ground last year. The rocks represented on the published maps as contemporaneous diorites, felstones, and ashes appear to be, at least in the great majority of cases, of truly intrusive character. In the case of the fragmentary masses the resemblance to agglomerate and ash is regarded as largely due to crushing by earth-movements, while the rocks lay deep below the surface of the earth. It is further believed that both the early basic masses and the later acid series were intruded amongst the sediments in the form of laccolites, sills, and dykes. As in many instances the felstones pass gradually into granites of the same type as that of the Leinster mountain range, it may be inferred that these rocks belong to the same system of intrusions as the Leinster granite, which is of the age of the Old Red Sandstone.

The intrusive sheets examined last year, wherein this passage is most apparent, lie to the south-east of Enniscorthy. The felstone of Vinegar Hill in that district is sometimes brecciated, and shades gradually southward into a granitic rock, which, on the published map, has been classed as "Elvan." Again, ten miles to the south-west of Enniscorthy, the hill two miles south-west of Chapel Rail Station shows a central portion of the laccolite to be granite, which merges outwards all round into a felsite. Still further south-west (Sheet 168) the acid mass of Carrickburne Hill passes from a central granitic core into a felspathic rock, which presents flow and spherulitic structures, as well as considerable brecciation. At Knockcarroll (Sheet 168) another example of the gradation from a granitic into a felsitic rock is to be seen. The felsitic masses show more or less deformation or brecciation* where the crushing is most evident. Innumerable included portions of indurated sedimentary materials, sometimes fossiliferous, have been caught up in them. These inclusions vary in size from masses half a mile long down to the smallest particles, the larger examples having generally a lenticular form, and being arranged parallel to the general strike and crush-line zones of the country. Many small dykes mapped as "elvans" occur in the vicinity of both the larger felsitic masses and the granite.

* *Summary of Progress for 1899*, p. 179.

Mr. Egan
and Mr.
McHenry.

Brecciation has taken place to a considerable extent in the felsitic bands, notably in the Tara Hill mass, to the north-east of Gorey, and in the large knoll to the W.S.W. of Ballycanew (Sheet 149). It is displayed in many places in the Enniscorthy area, and further southwards (Sheets 168 and 169). Fine examples may be seen in Carrickburne Hill, where the broken-up felsitic fragments exhibit flow-lines, and are enveloped in a matrix showing spherulitic structure. Specimens of all these rock-varieties were collected, but have yet to be examined and reported on.

The revision of the Silurian areas in the counties of Wicklow and Wexford has thus shown that the rocks represented on the published maps as felstone-lavas are in large measure intrusive sheets, and that the so-called "greenstone-ash" consists of more basic dykes and sills, which have acquired a fissile or schistose structure owing to intense deformation. A revision of the mapping of the igneous rocks of this region would thus greatly reduce the number of rocks of truly volcanic origin. That such rocks, however, exist in the Silurian series of this part of Ireland appears to be sufficiently established. Thus, on the sea coast north of Courtown (Sheet 149), between Duffcarrick and Ballymoney Fishery, bedded tuffs are well exposed. The Director-General, after having visited the locality in two successive years, made the following notes on this coast-section:—

Director-
General.

"In again traversing the Duffcarrick shore from south to north I was once more struck by the evidently intrusive character of the felsites at the south end of the section. These rocks are not uniform in texture, some parts being close-grained and flinty, others more granular-crystalline, while certain pale decomposing portions show a porphyritic structure. As they are traced northwards, an increasing number of fragments of black and grey shale are seen to have been caught up in them. These enclosures are generally arranged parallel with the planes of rude cleavage by which the felsites are traversed. Then come highly-inclined and disturbed lenticular bands of grey and black shale, much compressed and drawn out between the felsite intrusions, and succeeded thereafter by thick continuous bands of similar shales. The black shales have yielded graptolites which prove the strata to belong to the Llandeilo group. A little north of the first thick band of black shale there comes in a group of grey shales full of lenticular bands and lenticles of brown ferruginous limestone, belonging to the Bala group. The distance measured across the strike between the last visible exposure of the black shales and the first observable members of this calcareous series is 27 yards. This interval is obscured by the sand of the beach. At the most there cannot be more than 80 feet of strata between the representatives of the Llandeilo and Bala sub-divisions, but the relations of the two groups are unfortunately concealed.

"The bedding of the Bala group, owing no doubt to the greater diversity of the strata, is more distinct than that of the black shales. It can be seen to undulate towards the south-east at angles of 35 deg. and upwards. But the calcareous strata have

been intensely cleaved, the planes of cleavage being nearly vertical and running in an E. and W. direction. Immediately beyond these strata, after a concealed space of a few feet by which the relations of the rocks are at present concealed under the accumulations of the beach, a remarkable brecciated conglomerate makes its appearance in distinct beds which dip gently towards N.E., that is away from the Bala Limestone. This fragmentary series of strata contains abundant fragments of limestone, and also rolled shells and corals from that rock, and pieces of Llandeilo black shale. It has been so intensely cleaved that the pebbles have often been turned round so as even to stand at right angles to the bedding. The matrix is a fine felsitic material which encloses numerous small lapilli of felsite and other igneous rocks. If this matrix has not been derived from volcanic discharges, it must at least have resulted from the degradation of volcanic rocks exposed to aqueous action. The conglomerate or breccia passes rapidly upward into fine grits with thin partings of shale, and is soon succeeded further north upon the shore by Llandeilo black shales and "ribboned slates," which are believed to belong to the Arenig division.

"These conglomerates and grits are obviously younger than the Bala Limestone. They may form the base of some later member of the Silurian series, but no clue has yet been obtained as to their true age and stratigraphical position. Their intense cleavage shows that they must be more ancient than at least the later movements by which the older Palæozoic rocks of this region were affected. Not improbably they may eventually be shown to be of Llandovery age, marking, perhaps, the base of the Upper Silurian series in this part of Ireland. If it can be established that the matrix of some portions of the conglomerates and grits is of the nature of volcanic tuff, it would be an important addition to our knowledge of the history of volcanic action in this region.

"Further north a remarkably interesting section is exposed near Ballymoney Fishery. A coarse agglomerate rises there in a bold cliff along the inner margin of the beach. Along its southern border it presents a nearly vertical junction, probably a fault, against a mass of black Llandeilo shales. Entirely unstratified, it is crowded with large and small blocks of black shale and various felsitic rocks. Like the calcareous conglomerates and grits further south, it has been greatly cleaved, and the enclosed fragments tend to range themselves along the vertical or highly inclined planes of cleavage. This rock may mark an actual volcanic neck or orifice of eruption. If so, its origin must at least date back from an earlier time than that in which the cleavage of the rocks was completed. It appears to pass northward into a group of well-bedded breccias and fine grits, which have a south-westerly dip at angles varying from 15 deg. to 40 deg., and are made up of alternately coarser and finer detrital materials. Their highly felspathic composition suggests that they may have been largely derived from volcanic discharges. The cleavage which has affected them is similar to, though

Director-
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rather less strong than that of the adjacent rocks. In this section also it was impossible to trace the relations of these tuff-like strata to the surrounding Silurian rocks. At present the evidence strongly points to the existence here of true volcanic rocks; later probably than the Bala group, but older than the cleavage of the district. As the cleavage does not affect the Carboniferous Limestone of Wicklow and Dublin, we may infer that the volcanic episode occurred during some part of the long interval between the close of the Lower Silurian and the commencement of the Carboniferous period. The rocks do not resemble those of the Old Red Sandstone, but are not unlike some parts of the Upper Silurian formations. It may be added that nothing like these apparently volcanic strata of the coast has been detected anywhere in the interior of this part of Ireland."

Mr.
McHenry
and Mr. Sey-
mour.

After the completion of the revision of Co. Wexford, and having joined up boundary-lines with MR. KILROE, working northwards from Waterford, MR. McHENRY was employed with MR. SEYMOUR in the re-examination of some portions of the ground north of Dublin, especially with the view of applying the knowledge acquired during the recent field-work in Wicklow and Wexford to the investigation of the rocks shown on the published map (Sheet 91) as felstone and diorite. The result of this re-examination has been to show that the so-called "felstones," and some of those classed as "diorites," are really composed of detrital materials (arkose). As these coarse fragmental strata always occur close to Lower Silurian fossiliferous rocks, they may not impossibly represent the basement beds of the Upper Silurian formation, especially as close to them fossiliferous Upper Silurian strata (Llandovery) are found in place. This conjecture may perhaps strengthen the inference that seems to be indicated by the shore-section between Duffcarrick and Ballymoney above described.

In the ground hitherto mapped as Lower Silurian, to the north-west of Balbriggan, fossils of Wenlock age were last year obtained. Another traverse was made by MR. McHENRY of the high ground lying to the W. of Newtownmount-Kennedy, with a view to determine to what extent the "green grits and slates" of the published maps were of sedimentary origin. From the examination of a limited area it would appear that these rocks are mainly basic igneous masses of andesitic types (calc-diabase).

Towards the close of the season, MR. McHENRY and MR. SEYMOUR visited the dyke-region of Co. Down for the purpose of determining the relative extent of the basic and acid intrusions in that part of Ireland. A detailed account of the petrographical results prepared by MR. SEYMOUR will be found at p. 161.

COUNTIES KILKENNY, WATERFORD, AND WEXFORD.

Mr. J. R.
Kilroe.

The revision of the Silurian tracts of the extreme south of Ireland has been completed by MR. KILROE, who has joined up

his boundary-lines with those traced southward by MR. MCHENRY. Mr. J. R. In regard to the sedimentary rocks, he reports that west of the Barrow in Kilkenny they are almost destitute of fossils. Only a few slender iron-stained stems and fucoid markings have been found in the fresh rock of the sections laid open in the cuttings of the extension railway now being made from New Ross to Waterford. In Wexford, MR. CLARK confirmed the occurrence of fossils in some localities in the vicinity of Duncannon and Arthurstown where they were formerly obtained, and discovered a new locality, three miles west of Wellington Bridge (Sheet 169), near Ballinruane House. It would appear that a zone of Lower Bala rocks strikes north-eastwards from Duncannon; and that another zone characterised by a somewhat higher facies of fossils extends from Ballyhack (Sheet 168) towards Burkestown Cross Roads. At Waterford, the dark gray slate and grit series of Gibbett Hill has yielded double graptolites of Bala age; and, according to the lists published in the Survey Memoir, and more recently by MR. COWPER REED, the strata of the well-known locality of Raheen near Newton Head on the Barrow Estuary, are of the same age.

It is probable that southward from the strike line of the Silurian strata, running east by north from Waterford across to the Old Red Sandstone, and on to Duncannon in Wexford, Bala rocks prevail—possibly to the exclusion of other divisions of the Silurian series. No strata possessing the usual characteristics of the Llandeilo group have been met with within the zone. Black slate occurs in many places in the district, but without fossil evidence it cannot be shown to be lower than the Bala group, which in this region includes much black slate containing Bala fossils. Graptolites of the species *G. Hisingeri* are reported to have been found in the dark gray slate a little north of Bagginbun (Sheet 180)*, but recent re-examination has failed to confirm this statement, and no means now exist of verifying the determination of the species.

Two small inliers of Silurian strata, surrounded by Old Red Sandstone, occur to the south and south-west of Mullinavat. They consist of green, greenish-gray, and dark gray slates and grits, which so far have not yielded any fossils. The grits contain a good deal of felsitic matter, and it is worth noting that adjoining the basic igneous mass, shown in the Rathkieran inlier, lies a breccia of igneous materials, which does not seem to be fault rock. This rock shows a structure which resembles bedding, but its exact relation to the igneous mass has not been determined. The latter is in parts vesicular. Round the larger bosses of granite where the Silurian grits and slates have undergone alteration, the development of mica becomes well-marked as the strata are traced towards the igneous rock. Spotted schist has been noticed at a few points within the metamorphic fringe. Schist, with fairly well-formed crystals of chialtolite, occurs on the high road at Brownsford, and at the farmyard of Newgrove House, south-east of Inistioge.

* Memoir on Sheets 169, 170, 180, 181, 41 59.

Mr. J. R.
Kilroe.

During the revision of the Silurian tracts of this part of Ireland, as in the regions further to the north, advantage has been taken of the opportunity to re-examine the igneous rocks which play so large a part in the geological structure of County Waterford. The results of this re-examination have been briefly stated in previous *Summaries of Progress*. The work of last year has confirmed the results already obtained. There can be no doubt that here, as in Wexford and Wicklow, many of the rocks which have been mapped as felstone-lavas are really intrusive bosses and sills, and that some at least of the "ashes" are not tuffs, but crushed andesites or felsites. At the same time clear evidence can be found that true andesitic and felsitic lavas and tuffs are intercalated in the Lower Silurian series of Waterford.

Reference was made in the *Summary of Progress* for 1899 to the green grits and conglomerates which overlie and are partly made up of fragments of the andesites that occur at Ballyscanlon Lough. Some of the coarser sediments, such for instance as those at Cullen Castle, are probably volcanic agglomerates that may mark some of the volcanic vents of the time. Similar green fossiliferous grits and slates occur at Knockmahon and along the coast to Ballydowane Bay. The occurrence of these rocks, composed in large measure of volcanic detritus, yet containing undoubted Bala fossils, points to volcanic action, probably on an extensive scale in this part of Ireland, during the deposition of the Bala division of the Silurian system. Further interesting corroboration of this conclusion was obtained by the Director-General, who supplies the following notes of his observations along the coast-line during his tour of inspection last year.

Director-
General.

"The rocks on the shore at Knockmahon consist of fine purple and green grits, with corals, brachiopods, and fragmentary fossils. They rest on the uneven surface of an amygdaloidal and nodular rock, probably an andesite, which may represent one of the lavas of Bala time. Some of these fragmental strata closely resemble the remarkable breccias which have been described as occurring near Dunhill Bridge, save that they are crowded with well-preserved fossils which are absent in the Dunhill breccias.

"Much clearer in its evidence is the section exposed at the base of the cliff on the western side of the little bay, immediately to the west of Bunmahon Head. There an augite-andesite rises from the beach, and displays a characteristic development of the ellipsoidal or pillow-shape structure so characteristic of many basic and intermediate lavas of Palæozoic and later periods. The ellipsoids are irregularly ovoid in shape, and vary from a couple of inches to two or three feet in diameter. Many of them show a finely vesicular external layer or shell. In the interspaces between them, to a depth of at least three feet from the upper surface of the lava, fine sediment has descended from above. This material has solidified into a compact felsite-like substance, in which traces of stratification may be detected. It has evidently been washed from above at the time when the lava lay under water and presented a surface of elliptical blocks,

either loose or only slightly attached to each other. Above the andesite comes a thick series of well-bedded volcanic grits like those of Knockmahon. The stratification is well shown by the parallel stripes of darker and lighter tint up the face of the cliff, the inclination of the strata being towards north-west at 15 deg. Some of the more flinty bands correspond with the felsite-like material that has filled up the interspaces between the ellipsoids of the underlying lava. Director-General.

"The geological record revealed in this section appears to me to be of the highest interest in regard to the interpretation of the whole volcanic history of this region. It proves the existence of a true lava covered by fine tuffs and volcanic grits contemporaneously associated with the Bala rocks of the coast. I was particularly struck with the felsitic aspect of some of the finer bands in this series of sediments, and with the deceptive resemblance to intrusive veins presented by the similar material between the lava-ellipsoids. This material recalled some of the finer and apparently felsitic portions of the agglomerates further east, which here and there invade the surrounding rocks. In the present instance there could be no doubt of its clastic origin, and one could not but suspect that some at least of the agglomerates between Knockmahon and Tramore may after all, notwithstanding the strikingly felsitic character of their matrix, be pyroclastic rocks, and not felsites brecciated *in situ*. For the purpose of testing this question by the help of the microscope I requested MR. SEYMOUR, who accompanied Mr. KILROE and myself in this visit, to have some thin slices cut from the most flinty parts of the fine material filling up the interspaces in the Bunmahon andesite, and to compare it with the fine matrix of some of the agglomerates further east. He has supplied the following report of his examination:—'The yellowish-grey banded rock filling up the interstices in the "pillow lava" W. of Bunmahon Head and regularly stratified on top of it, is in section a typical, fine-grained tuff. The base, though almost felsitic in places, is certainly fragmental, and is composed of the very finest felsitic (devitrified glass) particles, the clastic origin of which is, however, more apparent as the size increases. It contains numerous fragments of quartz, some of them containing glass-inclusions, and many of them showing conchoidal fracture. A few fairly basic plagioclases occur, and are probably derived from the breaking-up by volcanic explosions of a rock similar to the under-lying lava. A few pieces of a flaggy devitrified felsite occur in the section, also some greenish patches of chloritic matter. The rock is, on the whole, decidedly acid in composition. It is practically identical in every way with the fine-grained matrix of the Dunhill tuff, and compares very closely with the base of the agglomeratic rock near Sheep Island.* That rock is pyroclastic, and its matrix is in places very like that of the rock from Bunmahon.'

Another striking series of dark green volcanic grits occurs 5 miles to the north-west of Tramore, in the north-western

* See *Summary of Progress for 1899*, p 80.

Kilroe. portion of Sheet 179. The grits contain numerous fragments of light gray felsite, many of which are rounded, and in general showing flow structure, embedded in a clastic matrix which is often very compact in texture. Bedding is seldom to be observed, though a more or less perfect cleavage traversing the mass gives the appearance of stratification. This series seems to be invaded by the felsite which bounds it eastward, and possibly also by that which bounds it on the N. and S. Similar green grits stretch north-eastward from Ballynamona towards Mount Druid (Sheet 178), near to which the fragmental rocks are associated with a vesicular basic mass. Fragmental rocks of the same character appear on each side of the Barrow at Ballinlaw Ferry, N. of the junction of the Barrow and the Suir.

An interesting section has long been known to be exposed on the coast of Waterford Harbour, at Raheen, near Newtown Head, where the best succession of volcanic rocks in the district is associated with fossiliferous strata of Lower Silurian age.* These rocks comprise spherulitic and flow-structure felsites; gray tuffs and volcanic grits, and dark grey sandy fossiliferous grits.

The horizon in the Lower Silurian of these rocks is fixed by the fossils in the associated grits. MR. COWPER REED in his paper cited below appears to ascribe the series to Lower Caradoc, placing it just above the *Dicranograptus* zone of Wales. He considers also that local facts in the Waterford area justified him in placing the zone mentioned, and consequently the Raheen rocks, at a higher horizon than the Tramore limestone. MR. KILROE, however, believes this limestone to be of Bala age, and that the Raheen series stands at least equally high in the formation. The occurrence of limestone and calcareous grit similar to those of the Tramore series, in the volcanic succession at Newtown Head, and the fact that a slight divergence is noticeable between the fossil facies of the Tramore and that of the Raheen series, would seem to indicate that the latter represents a higher horizon than the former, as indeed MR. REED, upon other grounds, maintains. If this be so, the Raheen series might be regarded as belonging to the Upper Bala (Caradoc) period.

On the Wexford side of the estuary opposite Cheek Point, and inland four miles east by north, near Killesk Cross Roads, gray grits are associated with fragmental rocks which may be true tuffs. On the shore of Great Island also opposite Cheek Point tuff-like rocks occur in proximity to gray grits, with bedding conformable to small limestone bands.

The true lava-form characters of the sheets seen on the Raheen shore may be taken as a guide in the interpretation of similar inland rocks, of which the relations are much less clearly seen. Thus the felsites near Dunbrody and near Waterford with flow-

* See Survey Memoirs, Explanation of Sheets 167, 168, 178, and 179. Ireland, pp 25, and 41. The Section has recently been described in much more detail by MR. F. R. Cowper Reed, *Quart. Jour. Geol. Soc.*, vol. lv. (1899), p. 721.

structure and fragmental accompaniments are probably lava- Mr. Kilroe.
flows.

Some of the felsite masses in South Waterford and Wexford contain detached portions of basic material, possibly including fine grained grits. This may especially be seen in, though not limited to, the case of the light greenish-grey felsites which form the rugged track extending from Sugarloaf Rock (Sheet 168), south-westward towards Ballyphillips (Sheet 179), particularly at Sporthouse and some 50 yards north-west of the point where the roads cross, half a mile east by north of Shinganagh Cross Roads. These felsites, however, are not very distinguishable from those which seem to be earlier, though, on the whole, they are more coarsely crystalline in texture. If they are classed amongst the youngest acid rocks in the region, they may correspond in age with those which pass into granite and "elvanite" near Mount Druid, and on the east side of the Barrow (Sheet 168).

Besides a narrow band of granite which extends from Mount Druid north-eastward, and resembles a fine-grained variety of that of the Dublin and Wicklow range, a few granite protrusions of probably the same age appear in south-west Wexford, and at Rochestown in south Kilkenny. At the last-named point the granite is quite like that of the range; while the few small outcrops east of Dunbrody are quartz-felspar rocks with granitic texture, almost if not quite devoid of mica. They are represented as "elvanite" on the published map.

The results of MR. SEYMOUR'S study of the petrography of the Silurian districts of the south-east of Ireland will be found on p. 165.

In conclusion, it may be repeated here that the re-examina- Director-
tion of the igneous rocks which has been made during the General.
revision of the Silurian tracts of the south-east of Ireland has shown that considerable modifications will be necessary in the representation of these rocks upon the published maps. In particular, the areas occupied by the intrusive masses will require to be considerably extended, and those of the lavas and tuffs to be proportionately reduced; the petrography will need revision, many of the so-called "felstones," for example, being undoubtedly andesites, and the agglomerates will require to be discriminated. But such a thorough revision of the ground would really amount to a re-survey, and would take several years of sedulous work both in the field and in the laboratory. In view of the other pressing duties of the Geological Survey of Ireland, it has not been deemed expedient to undertake this labour for the present. It must remain as one of the tasks of future years.

Devonian.

CORNWALL.

In continuation of his previous field-work, MR. USSHER has Mr. W. A. E.
been engaged in the districts of Pillaton and Liskeard in East Ussher.
Cornwall, in mapping the Middle and Upper Devonian rocks, and the Lower and Middle Culm-measures.

Mr. W. A. E.
Ussher.

The discovery made in 1899 of the identity of the Polperro beds with the Dartmouth slates necessitated the insertion of a boundary for these beds throughout the Lower Devonian area. This boundary had been drawn in the Kingswear promontory, where it is well marked, during the survey of that district, and in the Looe district in 1899; but, in the intervening area, it is often exceedingly indefinite and uncertain.

The identification of the fossiliferous rocks of Looe, in Devonshire, is a matter of still greater importance. In that district the stratigraphical evidence for the relative position of these rocks and the Polperro beds (or Dartmouth slates) proved to be inconclusive. The settlement of this question would resolve all the doubts entertained as to the stratigraphical succession and the structure of the Lower Devonian areas throughout South Devon and Cornwall.

Lithologically, and in their modes of association with the slates in which they occur, the fossiliferous rocks of Looe have their counterparts in the Torquay promontory, in the Kingsbridge district, and in other parts of the Lower Devonian area. Palæontologically, the distorted fossils at Looe are regarded as Gedinian;* whilst those of rocks of similar lithological types, in Devon, belong to much higher horizons in the Lower Devonian, viz., Upper and Lower Coblenzian. Amongst the Looe fossils identified by DAVIDSON are *Rhynchonella pengellyana*, Davidson, and *Spirifer primævus*, Steininger. The first named is given by SANDBERGER, with six other fossils, as occurring only in the Onychian Sandstone (the base of the Lower Devonian), and in no newer subdivision of the Lower Devonian. *Spirifer primævus* is given as common to the Onychian Sandstone and the overlying Rhipidophyllen or Hunsrück-Schiefer.

In his "Supplement to the British Devonian Brachiopoda," p. 4, DAVIDSON, referring to fossils collected by the REV. G. F. WHIDBORNE from the Lower Devonian beds in Saltern Cove Railway-cutting, observed:—"I thought I could recognise among them *Spirifera levicosta*, *Rhynchonella Pengellyana*, *Leptaena Looensis*, *Orthis hipparionix*." The strata in Saltern Cove Railway-cutting are, certainly, above the Dartmouth slate series, and are unhesitatingly regarded as a part of the Cockington beds (Coblenzian). The fact that the fossils referred to in the above quotation were casts would equally apply to the original specimens from Looe. The fossils collected in the Looe district in 1899 were sent up to Jermyn Street, together with fossils from Torquay obtained in the past year. Amongst the Looe fossils is *Spirifer primævus*.

During the survey of the Kingsbridge area, crushed impressions of *Spirifers* resembling *S. primævus* were obtained at Ringmore

* Doubtfully correlated by SANDBERGER with the Grauwacke of Montigny in the Ardennes, the Rhipidophyllen Schiefer of the Hunsrück, Eifel, and Taunus districts, and the Siegen grauwacke of Nassau. *Jahrb. d. Nass. Ver. f. Nat. Jahrg.* 42.

and elsewhere. At Ringmore a large eye of *Phacops*, which DR. **Mr. W. A. E. WOODWARD** thinks may belong to *P. Ferdinandi*, was also found. **Ussher.** These fossils, with others, from rocks in Devon and Cornwall which correspond in character with the various types of the fossiliferous rocks of the Looe district, will be submitted for examination by the Geological Survey Palæontologist.

As regards the Torquay promontory, greater experience, obtained since the original survey in 1888, has enabled MR. **USSHER** to detect an unfaulted junction between Middle and Lower Devonian strata, and to recognise Lower Devonian types met with in other parts of the area.

In the south-west of Cornwall MR. **WILKINSON** has mapped **Mr. Wilkinson.** the sedimentary rocks between Whitecross, near St. Erth, to Leedstown. These strata are regarded by MR. **HILL** as belonging to the fourth or Mylor subdivision of the rocks in the Falmouth district.

In continuation of the work of previous years, MR. **HILL** has **Mr. Hill.** pushed westwards the survey of the area enclosed between Helford River, Gerrans Bay, and the upper estuaries of the Fal, towards the metalliferous districts, of which Camborne and Redruth form the principal mining centres, and he has commenced the examination of the mineral tracts themselves.

The sedimentary rocks met with comprise lithological divisions the broad characteristics of which have been sufficiently described in former Summaries. They consist of the Portscatho, the Falmouth, and the Mylor series. The igneous rocks include "greenstones," mica-traps, granite, and elvan.

The fact that the whole of this area contains nothing in the nature of a limestone, as well as the apparent absence of organic remains, become easy of explanation when it is realised that the strata form only a thin series which occupies a considerable breadth of country owing to a constant repetition by means of isoclinal folds. Besides the evidence of such plication, which is amply demonstrated by the results of the systematic mapping of the district, ocular demonstration of these structures may sometimes be seen in natural cliff sections.

The occurrence of "greenstones" in this district, so far as yet surveyed, is limited to ground between Devoran Creek and the eastern boundary of the Penryn granite.* These rocks are generally so far decomposed, and the sections so meagre, that neither their mineral composition nor their relationship to the rocks amongst which they occur can be satisfactorily determined. Originally they were probably dolerites, and possibly intrusive. One band of them remains in a fresh condition, probably owing to its original massive character. It is seen at Lower Treluswell and other localities. It is about 60 yards wide and follows an horizon parallel to the boundary of the granite, from which it is only divided at Burnthouse by a space of 150 yards, in which

* For the purposes of this Report the large mass of granite occupying so much of the broad tract of country between Redruth, Helston, and Penryn will be referred to under this designation.

Mr. Hill.

another "greenstone" of the decomposing type common to the district may be observed.

In petrographical character it is an amphibolite, which at Burnthouse is coarse in texture, and presents on its outer portion a compact fine-grained aspect and is equally fresh. Neither the coarse-grained interior nor the finer-grained margin exhibit any traces of foliation. Between Burnthouse and Ponsanooth the band is quarried for road metal. In this quarry the rock is seen to be a homogeneous amphibolite, green in colour, being made up almost entirely of a fibrous hornblende, the individuals of which often attain a large size, and the crystal faces occasionally exhibit a bronzy lustre. The mass, as seen in the quarry, shows no schistosity whatever. Between this quarry and the Burnthouse exposure a variety is seen which weathers in a coarse nodular form, and in which felspar is seen to be intermixed with the hornblende, but plays a subordinate part in respect to that mineral.

At Burnthouse the finer grained "greenstone" has also been quarried. This rock occurs about 90 yards from the amphibolite, and must have a width of at least 30 yards. It cannot be many yards from the margin of the granite. This mass is in a highly decomposed condition, and is sheared throughout. Its relations to the amphibolite bands are not clearly visible. Its position in the field would naturally suggest some connection with the amphibolite, but it has been entirely crushed down by shearing movements, while the latter has been to all appearance unaffected. While the massiveness of its structure would sufficiently protect the main body of the amphibolite, it is difficult to see how its marginal portions could have escaped those processes of deformation which have so profoundly modified the "greenstone" band adjoining. The study of the tectonic features of the district has certainly shown marked differences of behaviour under stress between rocks which are homogeneous and those of heterogeneous character; while the latter have been broken down the former have remained intact. The suggestion may be offered that possibly the amphibolite, which is composed almost entirely of hornblende, owes its immunity to this cause, and that the "greenstone" which is broken down, being composed, like the other sheared varieties of the district, of a mineralogical mixture in which felspar has been generally an important ingredient, owes its deformation to its heterogeneous composition.

It may be remarked that all the "greenstone" bands so far mapped in the district are found in the Mylor series, and that both the bands which have been here described occur in the aureole of contact-alteration which encircles the granite mass, and to which allusion will be made later. While "greenstones" are associated with the Mylor series, the Portscatho division contains within its limits an assemblage of mica-traps, which have marked resemblances in the field to the lamprophyres that occur amongst the schists of the Scottish Highlands. They have been noted exceptionally in the Falmouth series, and one is seen to pierce the Nare Point conglomerate.

Although these mica-trap sills are everywhere in a highly Mr. Hill. decomposed condition, they are markedly different from the "greenstones." Nothing in their appearance suggests metamorphism. The type of alteration which they have undergone is rather that of decomposition under atmospheric influences. These rocks present a rusty brown aspect in the field, and are so weathered that fresh specimens have not been obtained, and they have not yet been submitted to microscopic examination. They occur as sills amongst the slates, on which they have effected a limited amount of contact-alteration, confined to indurating and sometimes converting them into hornfels to a distance of 6 or 9 inches from the edge. The same mass which lies between the strata as a sill may suddenly divert its course and behave as a dyke, and small veins have been discharged from them into the adjoining strata. They vary from a foot in width to 50 yards. In many instances spheroidal weathering may be observed among them, cores of more solid material being encircled by concentric outer layers of exfoliating material. Flow-structure is not uncommon, being especially noticed in the finer-grained marginal portions. In some rocks exhibiting flow-structure the spheroidal cores are elongated in the direction of flow, while rounded inclusions of quartz may be seen with their long axes in a corresponding position. Notwithstanding the advanced state of decomposition, the ground mass of these rocks can generally be seen to consist of a medium-grained admixture of biotite and felspar, while inclusions of quartz and crystalline felspathic rock are characteristic. Inclusions of slate are also frequently seen. The quartz and felspar-inclusions vary considerably both in size and shape. The quartz has been observed in masses as large as 9 inches, which grade downwards to the smallest dimensions. The inclusions both of quartz and felspar have often been perfectly rounded, while in other cases they have a brecciated appearance. Sometimes both quartz and felspar occur in perfectly rectangular fragments. These rocks vary considerably in their texture, some being as coarse as large-grained dolerites while others assume the texture of basalt. The mica-traps probably vary in acidity; in some the undecomposed cores seem to be made up altogether of felspar. In one of them which is deeply weathered and contains these acid cores, the mica is white, probably due to bleaching. Although quartz is so prominent as included individuals, it does not appear to enter into the composition of the matrix. In the largest and coarsest sill, although the texture of the rock is fine towards the margin, the biotite crystals retain their normal dimensions.

These mica-traps would appear to have been intruded after the slates had been cleaved but before the cessation of the stresses, which have acted on a part of the crust sufficiently within the zone of fracture, that instead of the strains finding relief in a system of fissures more or less divided, the mass has been everywhere free to give way, so that the entire crust is minutely fractured and converted on a large scale to what may

Mr. Hill.

be termed a regional breccia. Consequently these rocks occur as discontinuous patches, and cannot be followed for more than a short distance. Some of the joints of the sills are parallel to the movement planes in the adjoining slates, and there is a tendency to a parallel structure corresponding with these joints. Many instances may be observed where the minor faults in the slates have also affected the mica-traps and heaved them. These rocks, besides being affected by fractures subsequent to their consolidation, have sometimes been injected into brecciated strata, so that what would have been a single sill is represented by two or three discontinuous veins. Moreover, brecciation has continued after the consolidation of the erupted material, the slate along the margin exhibiting a curious zone of very fine brecciation which has been brought about by stress acting on the indurated margin that has been hardened by the sill.

Old Red Sandstone.

SOUTH WALES.

Mr. A.
Strahan and
Mr. Cantrill.

In carrying on the surveying of the South Wales Coalfield it has been necessary to map the outcrops of the older rocks which fringe the Coal-Measures to the north and south. The district on the north side in Carmarthenshire, which has been surveyed by MR. CANTRILL, comprises the summits and northern slopes of the Black Mountains, and extends from the Twrch Fechan to the village of Trapp, near Llandeilo. The three subdivisions into which the Old Red Sandstone was separated near Abergavenny have been found to hold good also in the area now under examination. They consist in ascending order of:—

1. The Red Marl series, which includes a great thickness of red marls, frequently hard and sandy, with occasional thin beds of soft micaceous and hard gritty sandstone up to 10 feet in thickness. Many of the marl-beds contain small calcareous nodules, sometimes in such abundance as to become cornstones, and to resemble conglomerates. Such beds are well exposed in the Sawdde, and are to be seen in numerous brooks between Gwynfe and Trapp. The red marls rest on the green micaceous "tilestones" or uppermost group of the Silurian series, and themselves contain Silurian fossils for a distance of 5 or 6 feet above their base.

2. The rocks which constitute the main mass of the upper part of the Old Red Sandstone include at their base a series of pale-green and dull-red micaceous sandstones with subordinate marls and nodular cornstones. This green series forms cascades in the Sawdde Fechan, and is exposed in the Clydach, but especially along the valley of the Cennen. The sandstones have been quarried occasionally for walling, paving, and drain-tiles. Upwards the green rocks pass into a considerable thickness of alternating red sandstones and marls which form the greater part of the scarp-slope of the

Carmarthen Fans. About 50 feet below the top of the red sandstones there is a marked conglomerate, which is 10 feet thick at Careg yr Ogof, and consists of pebbles of vein-quartz and pale-red or green quartzite imbedded in a hard red siliceous matrix. The pebbles range up to 4 inches in length. This conglomerate and the red sandstone above it form the long dip-slopes running southwards from the Fans of Brecon and Carmarthen, but they gradually disappear westwards, so that the overlying subdivision or Grey Grits rests directly on the beds below. At the same time the Old Red Sandstone ceases to form the predominating scarp, the main line of Fans consisting of Mountain Limestone and Millstone Grit. Whether the disappearance of the red grits and conglomerates is due to an overstep by the Grey Grits, or to thinning out without unconformity, cannot yet be stated.

Mr. A. Strahan and Mr. Cantrill.

3. The Grey Grits and conglomerates vary from 6 to 30 feet in thickness. The lower beds are usually a white conglomerate charged with pebbles of white vein-quartz ranging up to nearly 3 inches in length. Upwards they pass into yellow sandstones and sandy shales which themselves merge into the Lower Limestone Shales. The white conglomerate closely resembles the basement-beds of the Millstone Grit. This subdivision is exposed on Careg yr Ogof, on the Twrch Fechan, and has been traced without interruption as far as Trapp, but appears to be thinning in that direction.

The Old Red Sandstone south and west of Gwynfe is traversed by several folds which have a general direction of W. 20 deg.—30 deg. S., and are therefore parallel to the strike. One of these, a faulted syncline, throws down the outlier of Carboniferous Limestone known as Careg Cennen into the valley of the Cennen some distance to the north of the limestone-escarpment. The lowest beds of the Old Red Sandstone, together with the Upper Silurian strata, are vertical or nearly so, and high dips prevail up to and beyond the base of the Carboniferous rocks. Measurements under such circumstances are difficult, but as far as our observations go, the Old Red Sandstone appears to be thicker along its northern outcrop than at Cardiff, and therefore to expand in the direction in which all the Carboniferous rocks lose thickness.

In the south crop the Old Red Sandstone has been examined by MR. TIDDEMAN as far as the western margin of Sheet 247. He finds no satisfactory section showing the sequence into the Carboniferous Limestone, but obtains evidence of overthrusting, by which the Old Red strata appear to have been pushed over the limestone. The rock seen is a very coarse conglomerate, with an abundance of pebbles of white and pink quartz and some other materials. The general trend of the anticline by which it is brought to the surface is E.S.E. and W.N.W., and it also runs through Cefn-y-bryn, a fine

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Mr. Strahan and Mr. Tiddeman. ridge rising to a height of 600 feet. In Three Cliff Bay the conglomerate is faulted against much-dolomitised thin-bedded limestones, which probably lie low down in the limestone-series, but above the Lower Limestone Shales.

INVERNESS-SHIRE.

Mr. Horne. From his station at Daviot MR. HORNE was in a favourable position for studying and mapping the base of the Old Red Sandstone in Strath Nairn. He reports that the basement of the conglomerate in that district presents remarkable evidence of its derivation from the crystalline rocks of the immediate neighbourhood. To the north of Loch Duntelchaig, and near its outlet, where the muscovite-biotite-gneiss is largely developed, both the matrix and the included blocks of the conglomerate have come mainly from that rock. Again, further down the valley of the Nairn, west of Mains of Faillie, the conglomerate is chiefly composed of granitic detritus. The larger pebbles consist of porphyritic biotite-granite, resembling that *in situ* on Beinn a' Bheurlaich, two miles to the east, which forms a part of the Moy mass. These are associated with small subangular blocks of micro-granite, porphyrite, quartz-porphyry, lamprophyre and granulitic gneiss. The matrix is a coarse arkose, derived presumably from the disintegration of granitic rocks.

ROSS-SHIRE.

Mr. Peach. The mapping of the older rocks in the Eastern part of Ross-shire continues to reveal occasional outliers of Old Red Sandstone, which prove the former wide extent of that formation and the great denudation it has undergone. MR. PEACH reports that the mass of coarse breccia which caps Ben nan Cabag, north of Loch Luichart, partly reported upon last year,* and originally discovered by MR. GUNN† occupies a much greater area than was at first anticipated. Two smaller outliers, one only a few square yards in extent, lie between the Ben nan Cabag outlier and the Black Water. A third, which crosses the Black Water in line with these, about midway between Altquoich and the foot of Strath Vaich, may possibly be a tongue-like extension of the larger outlier of Meall a Ghrianain formerly noticed by MR. GUNN.‡

CAITHNESS.

Mr. Peach and Dr. Crampton. The tract of Old Red Sandstone mapped last season by MR. PEACH and DR. CRAMPTON extends as a broad strip across Caithness from the coast at Wick to Georgemas. In this area MR. PEACH reports that the main rock-type is a micaceous sandy argillaceous flagstone, often bituminous and generally containing

* *Summary of Progress for 1899*, p. 95.

† *Annual Report of the Geological Survey for 1896*, p. 53.

‡ *Loc. cit.*

more or less lime and iron-carbonate. When this rock is thinly and evenly bedded it constitutes the celebrated Caithness Flagstone of commerce. By admixture of different sediments it passes into flaggy sandstones, shales or mudstones, locally known as calmstones, or even into an almost pure limestone.

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Some of the flags and shales are so bituminous as to become impure oil shales, while albertite or mineral pitch is found distilled out into the faults and cracks of the strata over large areas in the western parts of the district. Marcasite and iron pyrites occur frequently as nodules throughout the series. Intercalated with the flags and shales are occasional beds of nearly pure sandstone, devoid of flaggy character. A small area of red or brown sandstone or coarse arkose and conglomerate or breccia is found at Houstry, near the southern edge of the area mapped. The colour of the rocks is for the most part a leaden grey, which becomes darker by the admixture of carbonaceous matter. The limestones are generally bluish grey, while the shales are usually lighter in colour than the flags. In the eastern district many of the rocks are of a greenish tint. All the rocks are liable on exposure to assume an ochreous colour from the decomposition of the iron-carbonates and sulphides contained in them, particularly in the neighbourhood of lines of crush, while near some of the faults and veins the rocks are liable to become bleached, and in places reddened by hæmatite.

Throughout the whole series of strata, sun-cracks, rain-prints, and other surface-markings occur on most of the bedding-planes, whence the inference may be drawn that the original sediments were laid down on a sinking floor, and were subjected to repeated periodical desiccation.

Along fault-lines, in addition to carbonates and quartz, the veins sometimes carry galena in small quantity. A few barytes-veins occur on the cliffs near to the Old Castle of Wick.

An important structural feature has been found in a line of fault which, with a trend from north to south, enters the area a little to the east of Castletown, and passing southwards by Hall of Durran, Bower Station, Old Hall of Dunn, leaves it on the crest of Backlass Hill. This is evidently the continuation inland of the fault which passes out to sea to the north of the village of Brough, and which has there the effect of bringing the Caithness flagstones on the east into conjunction with the overlying yellow Upper Old Red Sandstones of Dunnet Head on the west. From the nature and the amount of disturbance of the rocks on each side of the line of dislocation all along its course, the fault may be recognised as having been produced by an upthrust from the east. That the amount of displacement must be great may be inferred from the fact that everywhere the rocks on the two sides of the line are totally different from each other. The actual amount of upthrust is still unknown; but further investigation in adjoining areas may furnish a clue to it. In the meantime the line of fault supplies a convenient division of the ground into two unequal parts, which may be conveniently described separately. In the western or smaller subdivision the

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rocks are all more finely and evenly bedded than in the eastern and it is especially to be noticed that all the workable flagstones are confined to the west of the line. A few coarse flagstones are worked at Stonchone near Watten, on the east side, but they are very inferior, and are only used locally.

The lowest strata in the western sub-division are found near its south-west corner, in the neighbourhood of Achanarras. They consist of flagstones and flaggy limestones which have yielded a rich fish-fauna identical with that found south of the Moray Firth and in the Stromness district of Orkney.* They are almost horizontal at Achanarras, but with a tendency to dip towards the north and north-east. In the direction of dip these strata are succeeded by an alternation of flagstones and shales or calimestones, dipping in the same direction at angles of from 2 deg. to 5 deg. for about four miles. It is in this set of strata, at a level of about 200 to 300 feet above Achanarras, that the celebrated flags of Spittal occur, while those of Banniskirk lie, probably, a little higher still above the strata to be seen in Achanarras quarry. Near Georgemas Station a synclinal axis has been detected, north of which the flagstones dip gently to the south-east, and after rolling about or lying nearly flat for miles across a wide dome-like expanse corresponding with the hills of Stemster, Achingills, Hilliclay, and Olig, they finally roll over on the north slope of the Hill of Olig, and dip steadily towards the N.N.E., the highest beds occurring on the shore between Thurso and Clardon Head, outside the present area. The celebrated quarries of Stonegunn and Weydale lie just at the margin of the area now reported upon. The structure is, therefore, that of a syncline, the axis of which runs in a curved direction more or less E. and W. through Georgemas, and a dome to the north, the centre of which corresponds to the top of the high ground behind Stemster Hill. The fishes found in the Spittal and Banniskirk quarries are common to the Achanarras and Thurso beds. *Thursius macrolepidotus* occurs at Clayock, while DR. CRAMPTON obtained *Coccosteus minor*, a zonal form of the Thurso beds in the syncline to the N.E. of Georgemas Junction.† *Osteolepis microlepidotus* is found at Stonegunn and Weydale, and together with *Coccosteus minor* at Murkle. These two fishes are typical forms of the Thurso fauna. The strata at Achanarras quarry lie at least 900 or 1,000 feet below those from which DR. CRAMPTON obtained *Coccosteus minor*. MR. PEACH and he are therefore inclined to place in the Thurso group all the strata in the present area lying to the north and east of a line drawn a little to the north of Spittal and Banniskirk. All these rocks are in turn truncated by the fault. As they approach it they gradually swing round and dip towards it, but still nearer to it they bend

* See Dr. Traquair's paper in *Proc. Roy. Phys. Soc. Edin.*, vol. xli., part 2, p. 279.

† The determination of these forms in the field by the Survey Officers has been confirmed by Dr. Traquair.

up and dip steeply away from it, while in some cases they are even overturned. In a quarry on Corsback Hill the flagstones, which dip generally towards the east, show at intervals, lines of "staving" and overfolds accompanied by small overthrust-faults pointing to movement from the east. Mr. Peach
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Owing to the absence of fossil evidence the horizon of the strata on the east side of the fault is not yet known. Possibly the true structure of this ground will not be made out till the coast lines are studied in detail. The evidence afforded by the exposures in the area examined last year is that in the neighbourhood of the fault the strata are thrown into a succession of sharp folds, all of which have steep limbs towards the west, while some of them are overfolds. Small overthrust faults are also numerous. These phenomena are well displayed in the railway cutting near Bower Station. Similar structures occur on Backlass Hill and Houstry, at the south end of the line, where the lowest strata in the whole area are to be found. These consist of brown sandstones, arkose, and coarse conglomerate or breccia made up chiefly of fragments of granulitic "Moine"-like schists and granite*. They indicate that a local base of the series is here brought up near to the surface; they may represent a portion of the Berriedale Flagstone group. Beyond the immediate influence of the fault the strata, which are grey and dark, almost black, coarse-bedded flagstones with flaggy sandstones, dip persistently towards the east at low angles for about 4 miles, when they turn up for a short distance and dip westwards. A line of structure like that accompanying the great fault is then encountered, running approximately N. and S., the corrugated and shattered strata seamed with iron-carbonate being well displayed in streams at Croft of Quoy Brae, and also near Bilbster House. East of this line the beds dip gently eastwards to within about a mile and a half from Wick, when they once more bend up and dip westwards as far as the coast. On this limb of the syncline the strata are much more steeply inclined than on the western one, sometimes reaching an angle of 25 deg. The structure of this portion of the area is that of a double trough with approximately N. and S. axes, the line of upthrust fault representing the dividing anticline. The trough of the western syncline is close to the fault. The horizon of the highest beds is at present unknown. To what extent these strata are repeated on the east side of the fault can also in the meantime be merely conjectured; but near Ackergill, in the centre of the more easterly trough, DR. FLETT found a specimen of *Coccosteus minor*. DR. TRAQUAIR states that the fish which have long been known from the South Head of Wick, on the eastern limb of the syncline, and far beneath the Ackergill beds, are *Dipterus valenciennesii* and *Thursius macrolepidotus*. *Coccosteus decipiens* also occurs between Wick Bay and Noss Head. DR. TRAQUAIR regards the Wick and Ackergill beds as being the equivalents of part of the

* Dr. Flett, while making traverses in this district during the past year, observed these rocks and noted their significance.

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Thurso group. If this view be correct there must have been a great difference in the sedimentation of the two areas, as the Wick beds consist of alternations of flaggy sandstone with occasional true sandstone, almost pure limestones, calimestones, and few or no real flagstones. It seems as if the Thurso district lay in the centre of the basin in which the peculiar type of sediment of the Caithness and Orkney phase of the Old Red Sandstone was deposited. Before these points, however, are settled a much larger area of the county will require to be surveyed. Systematic fossil-collecting continued over a period of years seems to be the only method of gaining the required evidence.

ARGYLLSHIRE.

Mr. R. G.
Symes.

The mapping of the Old Red Sandstone series in the district of Lorne was continued last year by MR. SYMES. In the course of his survey he found to the west of Kilmelfort no trace of the basement conglomerate and sandstone that may be looked for at the base of the volcanic series, which here represents a range of precipitous escarpment winding by Daignish to Armaddy Castle for a distance of about eight miles. The absence of this sedimentary group may arise from several causes, the chief of which is no doubt to be found in the large amount of débris from the cliffs of andesite, whereby the ground is obscured where the outcrop would be looked for. One mile W.N.W. of Melfort House, under the cliff marked on the map as Druim Barr na Coille, bands of sandstone were observed to be intercalated with the strata of andesite, which on the south are thrown down by a N.E. and S.W. fault. Some of these bands are of economic value. They may be presumed to lie between the lava-sheets, since if they were the basement beds they might be expected to be conglomerates, which are generally the lowest beds in the Lorne district.

In the *Summary* for 1899 certain fragmental rocks which occur about a mile and a half north-east from Kilmelfort Hotel were referred to as conglomerates of Lower Old Red Sandstone age, but belonging to a higher horizon than that of the Oban or basement conglomerate.* During the present season these rocks were again examined by MESSRS. PEACH, SYMES, and KYNASTON, who have come to the conclusion that they are to be regarded as of the nature of volcanic agglomerates rather than ordinary sediments. Dykes of porphyrite have been injected into them. The matrix between their blocks is often of a crystalline igneous material with flow-structure, showing that the blocks have been involved and carried forward in actual flowing molten rock. These masses may, therefore, be connected with the flow-breccias mentioned in the last report.† From the local character of the materials and the mode of occurrence of these sheets of breccia

* *Summary of Progress* for 1899, p. 97. † *Op. cit.*, p. 100.

and agglomerate, it is probable that underneath this platform of volcanic débris one or more volcanic necks or vents may lie concealed. An actual neck which occurs a little to the south has already been described.* These necks and the platform of ejected matter in all probability belong to the later phases of the Lower Old Red Sandstone period of vulcanicity as manifested in Lorne. If this be the case, then, as the agglomerate rests immediately on the schist, this area must have escaped invasion by the earlier more basic lava-flows.

On the west side of the island of Luing several sills of felsite with blebs of quartz traverse the slates in the direction of their schistosity without affecting them as the basalt dykes do. Similar sills occur on the east side of Shuna and Torsay.

Lorne Volcanic Region.—In pushing the survey of Lorne further to the north and north-east, MR. KYNASTON has obtained results of great interest in regard to the history of the various igneous rocks associated with the Lower Old Red Sandstone of that part of Scotland. He has made a re-examination of the andesitic lavas and basement conglomerates between the main road leading to Glen Nant and the Pass of Brander. Beneath the lavas in this area there lies sometimes a conglomerate consisting of rounded pebbles of quartzite, andesite, and vein-quartz, and sometimes breccia, of angular fragments of the immediately underlying schists, such as black slate, limestone, phyllite, and epidiorite. As this basement-bed is traced northwards towards the Pass of Brander, it seems to undergo a gradual change, as if it had suffered a general induration. This alteration is especially noticeable at a distance of about half a mile from the Pass. The rock is not exposed, however, near enough to the granite to afford the means of deciding whether or not this appearance is due to contact metamorphism. Above the conglomerate, at from a half to a quarter of a mile from the Pass, certain strata appear with a banded or laminated structure, which in parts strongly resemble tuff, and show numerous small fragments of the underlying schists, though not resembling the typical tuffs, associated with the upper portion of the volcanic series. In their case also there is an appearance of induration. They are frequently full of greenish streaks and patches, from the presence of epidotic material. They may possibly be of sedimentary origin. The microscope does not bring out indications that can be regarded as conclusive of contact-action in them.

Above these banded beds come the normal pyroxene-andesites. They, too, present an indurated appearance, and are very refractory under the hammer. The microscope shows that they are augite-andesites of a basic variety, and that if they have suffered any contact-alteration it can only be slight. The rocks are so obscured by decomposition that accurate observations upon them are not easy. The abundance of small grains and granules of pyroxene seen in the ground mass [9031

* *Loc. cit.*

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and 9032] seems unusual. Very possibly it may be that these rocks are still too far (about three-quarters of a mile) from the granite for the question to be definitely decided either in the field or with the microscope; for although the older rocks below the andesites, on the south side of the Pass of Brander, distinctly assume the characters of hornfels, it does not necessarily follow that decided contact-phenomena should also be found in the lavas—assuming these latter to be older than the granite. For, other things being equal, we should not expect contact-phenomena to be exhibited at as great a distance from the intrusive mass in the case of igneous rock as in that of rocks of sedimentary origin. However this may be, there seems to be a decided difference, though rather of a general than a particular nature, between the andesites and basement beds near the Pass of Brander and similar kinds of rock at a greater distance from it. In the case of the Black Mount area, to be afterwards described, where the contact-alteration of andesites can be clearly demonstrated, the phenomena specially characteristic of such alteration in these rocks is imperceptible at more than a quarter of a mile from the granite. So that, even if contact-action could be shown to be entirely absent from the Pass of Brander andesites, three-quarters of a mile from the granite, it could not be concluded that they are therefore later than the granite-intrusion.

One other point is, perhaps, deserving of notice, though it may possibly have no special significance in this connection. At about a quarter of a mile from the Pass of Brander, a band of rock, not more than four or five inches broad, traverses the andesites. It has a somewhat coarse appearance for the size of the intrusion, and might almost be taken for granite. Under the microscope, however [9028], there are seen to be two generations of crystallisation, the phenocrysts being so numerous as to render the presence of ground-mass almost inappreciable in a hand specimen. The rock is of an unusual type in this district, and consists of idiomorphic plagioclases, quartz, often showing crystal outline, augite, green hornblende more or less altered into chlorite, and some chloritised biotite, while interstitial feldspar and quartz form the ground-mass. The two latter minerals occasionally form micropegmatite. The rock may be termed an augite-bearing microgranite. But its texture seems unusually coarse for so narrow a band, and there is no appreciable change of texture at its junction with the andesite, even under the microscope. It is not the usual type found in intrusive sills and dykes among the andesites; it resembles rather the more deep-seated type of intrusion met with in some of the porphyrites cutting the granites. But even in the granites an intrusion of such small size is usually of a compact texture. It suggests (like the phenomena of granite veins) that at the time of its intrusion the temperature of the surrounding rock was sufficiently high to allow of its cooling comparatively slowly. At the same time it is quite possible that conditions favourable to the formation of this type of intrusion in this particular area

may have been brought about by other causes than those Mr. Kynast^{on} specially connected with the intrusion of a large granitic mass. Finally, although certain phenomena near the Pass of Brander seem to be distinctly suggestive of contact-alteration, they do not furnish conclusive evidence that the intrusion of the Ben Cruachan granite was later than the andesites of this area.

How far the evidence of the Blackmount volcanic series affects this question will be discussed further on. If these rocks, together with those of Glencoe and Ben Nevis, can be shown to be of the same age as the lavas west of the Pass of Brander, the question of the age of the Ben Cruachan granite will be settled.

Close to the lower end of Loch Avich an exposure of agglomerate-like rock, which forms a conspicuous feature above Craignamoraig, and was mapped by MR. HILL in 1895, was revisited last year by MR. KYNASTON from Kilchrenan. The rock might at first be taken for the basement conglomerate, but closer inspection shows it to be rather of the nature of a coarse agglomerate. It may be followed for a hundred yards or so, close to the margin of the andesites. It forms a wall-like mass sometimes apparently against the andesites, and sometimes separated from them by the older schist. The fragments appear to have been derived entirely from the schists, vary considerably in size, and are almost invariably angular. Some parts consist of a fine-grained breccia in a reddish matrix, but more usually there is a confused assemblage of large blocks up to 6 feet in diameter, which consist of the coarse and medium-grained schistose felspathic grits and fine greenish grits and slaty beds, of the immediate neighbourhood.

Some sections show what is apparently a gradual breaking up of the schists *in situ* into angular fragments, as though an explosive outburst had torn away portions from the sides of a fissure. Possibly this agglomerate may indicate an infilled fissure (analogous to a neck), which may mark the site of some of the minor discharges of an explosive character, associated with the volcanic activity of the district.

The Ben Cruachan Granite.—From his station near Loch Creran MR. KYNASTON continued the mapping of the marginal portion of the north-western extension of the Ben Cruachan granite from near Ben Bhreac in a north-easterly direction as far as the head of Allt Buidhe, below the south-western spur of Beinn Sguliaird. The granite belongs to the more acid type, rather than to the dioritic modification of Bonawe and other places, and quartz may be clearly recognised with the naked eye. The texture is fairly coarse, even at the actual contact with the schists. Great difficulty was experienced in mapping out the boundary line between the granite and the schists, owing to the complicated nature of the marginal area. Indeed, in some places the granite and the schistose rocks are so intermixed that no sharply marked boundary-line can be drawn between them.

From time to time in former Reports allusion has been made

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to the complex character of the granite margin.* In the recently-mapped area, however, the margin of the Ben Cruachan granite shows these complexities to a greater extent and over a much greater area than has previously been observed. The contact zone consists of a network of sills, veins, bands, and tongue-like protrusions of granite, covering a belt of mountainous ground sometimes more than a mile broad. The vein-like offshoots do not, as a rule, anastomose with one another, but tend to run in a roughly parallel direction, coinciding with the original planes of foliation in the schists, although irregular intrusions of granite, having no apparent relation to any planes of weakness, are not uncommon. The complication is such that a line can only with difficulty be drawn between schists (hornfels), crowded with granite-veins and sill-like bands, and granite crowded with strips and inclusions of schist of every size up to a mile or more in length. The contact-area constitutes a zone of sill-like injections of great complexity. Towards the interior of this "injection-zone"—i.e., as we approach the main mass of the granite—the schists are frequently seen to be so impregnated with granitic material that it is impossible in a hand-specimen to distinguish the igneous portion from the material of sedimentary origin. The original finely-banded character of the schists doubtless largely assisted this impregnation (*injection lit par lit*). The same structure has also been observed close to the contact with the main mass of the granite, in the banded calcareous series of the Pass of Brander, where both "*injection lit par lit*" and "superposition" (Michel Lévy) may be seen sometimes in the same specimen.† Possibly both types may also be represented in the present case. There does not seem to be any definite zone of impregnation, but it may occur almost anywhere in the immediate proximity of veins, sills, or larger masses of the granite. It will also depend upon the structural character of the schists.

Further, in many places the schists have been broken up, under the process of injection, and a breccia has been formed—occasionally at some distance from the main mass—consisting of a confused mingling of altered schistose fragments in a granitic matrix. The fragments in the breccia are angular, and usually sharply marked off from the matrix. Occasionally, however, the outline is not well defined, and appears indistinct with a lens, showing, as it were, a gradual transition from the included fragment into the matrix. Such fragments are usually crowded with flakes of secondary biotite in more or less parallel layers, and are somewhat suggestive of the origin of certain ill-defined patches rich in biotite, occasionally seen in the granite. Occasionally the breccia assumes a coarse aspect, as is well seen to the west of Meall Garbh, the fragments measuring several feet in diameter. This structure was evidently

* See, for example, *Summary of Progress* for 1897, p. 89.

† *Summary of Progress* for 1898, pp. 84, 85.

an accompaniment of the intrusion and injection, and involves both homogeneous rocks, such as quartzite, as well as the banded schists. Good examples of quartzite-breccia were noticed at the granite contact in Glen Etive.*

Thus, in the marginal area of the granite every state of injection may be found from sill-like protrusions of the main mass many yards in breadth, to injections of microscopic dimensions. And similarly the granite displays included portions of the schists, varying from masses more than a mile in length to minute fragments. Even the smallest granite veins are of the same texture as the larger masses.

An intrusion of a fine-grained biotite-granite, or possibly diorite, was noticed near the head of Glen Dubh. The veins of coarse granite appear to end off abruptly against it, so it is possibly of slightly later date. It resembles some of the Kilmelfort types.

The Granites of the Blackmount and Moor of Rannoch.—A considerable area of granitic rocks was mapped last year from Kingshouse, on the western margin of the Moor of Rannoch, and about four miles from the head of Glen Coe. These granites include four principal varieties, all of which have close petrological relationships, and are intimately associated with one another, so as to form integral portions of one enormous mass. They constitute the north-easterly extension of the granites of Ben Cruachan and Glen Etive; so that a continuous tract of granite stretches from the Ben Cruachan area to the Moor of Rannoch. A traverse from the Moor of Rannoch south-westwards to the higher hills of the Blackmount, presents the four main types of granite in the following order:—

- | | | |
|---|---|---------------------|
| 1. Coarse foliated acid granite. (Moor of Rannoch type.) | } | Ben Cruachan types. |
| 2. Coarse acid porphyritic granite. (Marginal phase of Moor of Rannoch type— <i>c.f.</i> , the Glen Etive granite.) | | |
| 3. Hornblende-granite and quartz-diorite. | } | |
| 4. Pinkish acid granite. | | |

(1.) Moor of Rannoch type.—The normal type of rock which constitutes the floor of almost the entire eastern portion of the Moor of Rannoch is a coarse foliated hornblende-granite. It is a pale grey rock, consisting of plagioclase, orthoclase, quartz, green and brown hornblende, biotite, sphene, and some iron ore. The foliation indicated in a hand-specimen by the arrangement of the hornblende and biotite is scarcely perceptible under the microscope [9128], though strain shadows may be seen in the quartz. The orthoclase is often moulded upon the quartz. The rock has close affinities with the Criffel type of granite. Occasionally it contains large white porphyritic felspars. Huge angular blocks of this granite, scattered in confusion among the moraine-mounds, lend a striking character to the somewhat desolate landscape of the Moor, while, here and there, the bare rock is exposed in rounded hummocks, or rises as small islands

* *Summary of Progress for 1898*, p. 81.

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and headlands in the numerous lochans. As the exposures are traced eastward in the direction of Loch Laidon, the foliation gradually dies out and porphyritic feldspars are no longer seen. In the area about the head of Loch Laidon, the rock is of thoroughly granitic structure and occasionally becomes slightly finer-grained. Exposures are more frequent and the rock tends to form more prominent features. Similarly, the foliation dies out westwards a short distance to the west of Kingshouse and at the foot of the eastern slopes of Craig Dubh and Meall a Bhuridh. The foliated type gradually passes into

(2) A coarse acid porphyritic granite. This is practically the same as the typical Moor of Rannoch rock, but without the foliation. It may be regarded as a marginal phase. It is precisely similar in composition, structure, and texture to the coarse porphyritic granite which constitutes the marginal phase of the Glen Etive granite. This latter has been described in former Reports as constituting a central core within, and of slightly later date than, the Ben Cruachan granite. In a similar way the Moor of Rannoch granite has the same relations to the Cruachan type of granite on the western side of the Moor, except that the latter type does not in this case surround the former. Thus, the coarse porphyritic type, forming the western margin of the Moor of Rannoch granite, is succeeded to the west by the more dioritic variety of the Ben Cruachan type. The one type passes into the other rather abruptly, and sometimes the coarse porphyritic rock sends out veins into the Cruachan type. A vein of this kind is well seen in the granite crags at the north-western end of Craig Dubh. The junction between the two rocks is not very sharp, but constitutes a passage from the one to the other, expressed by a transition-zone of about an inch in breadth. The two rocks are closely allied petrologically—in fact, they have the same petrological relationships to each other as the Cruachan and Glen Etive granites, the latter being rather the more acid of the two.

(3 and 4.) Hornblende-granite, diorite, and pinkish granite, constituting the Ben Cruachan types. It is not necessary to enter into any detailed description of these rocks, as this has already been given.* The dioritic type, as has also been observed in the Ben Cruachan district, constitutes the more marginal modification, while the more acid type forms the more important bulk of the mass, including many of the higher hills of this part of the Blackmount, such as the Clachlet (3,602 feet), Aonach Mor (2,839 feet), etc. The diorite or hornblende-granite, when followed towards the inner part of the mass, appears to pass gradually and imperceptibly into the acid type. This latter, well seen in Corrie Ba and on the Clachlet, is identical with the rock forming the upper portion of Ben Cruachan. On the ridge of Craig Dubh the hornblende-granite is often much intermixed with the neighbouring quartzose and micaceous schists. These latter have frequently been broken up, and the fragments lie confusedly in a granitic matrix, which appears to flow round them.

* *Summary of Progress* for 1897, p. 85.

The different types of granite here described, their relations to Mr. Kynaston one another, and their behaviour in the field, indicate one closely connected whole. The mapping of the area from Ben Cruachan to the Moor of Rannoch clearly shows that the granites of Ben Cruachan, Glen Etive, and the Moor of Rannoch constitute a gigantic mass, which has assumed the form of a belt, about 10 miles broad (including the granite area on the west side of Loch Etive), with a general north-easterly and south-westerly trend. It is true that parts of this mass—the Glen Etive and Moor of Rannoch granites—appear to have been intruded at a slightly later date than the rest; but MR. KYNASTON believes that the interval between them was geologically insignificant, and that so far as this great mass has been mapped, it belongs in all its members to a single geological period. It is interesting to note in this connection that the trend of this belt of granitic rocks is similar to the general trend of the planes of foliation in the older schists. The numerous dykes and sills have had the same tendency impressed upon them, and the planes of foliation observed in part of the Moor of Rannoch granite follow similar lines.

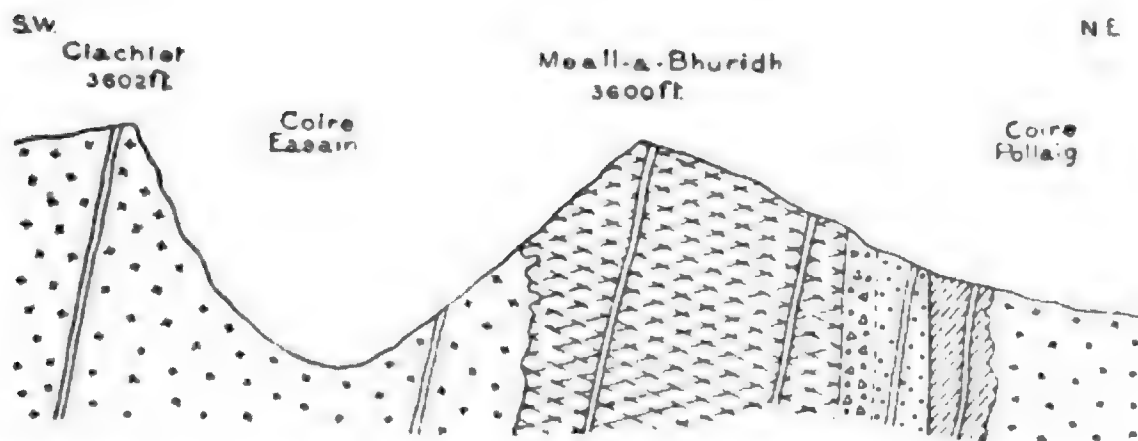
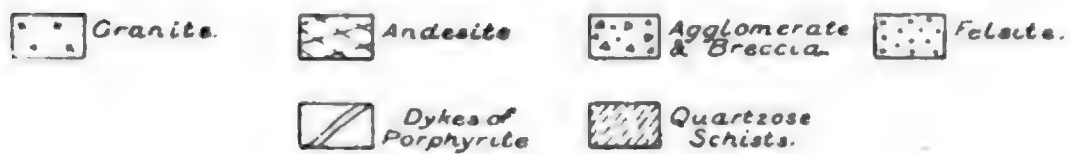
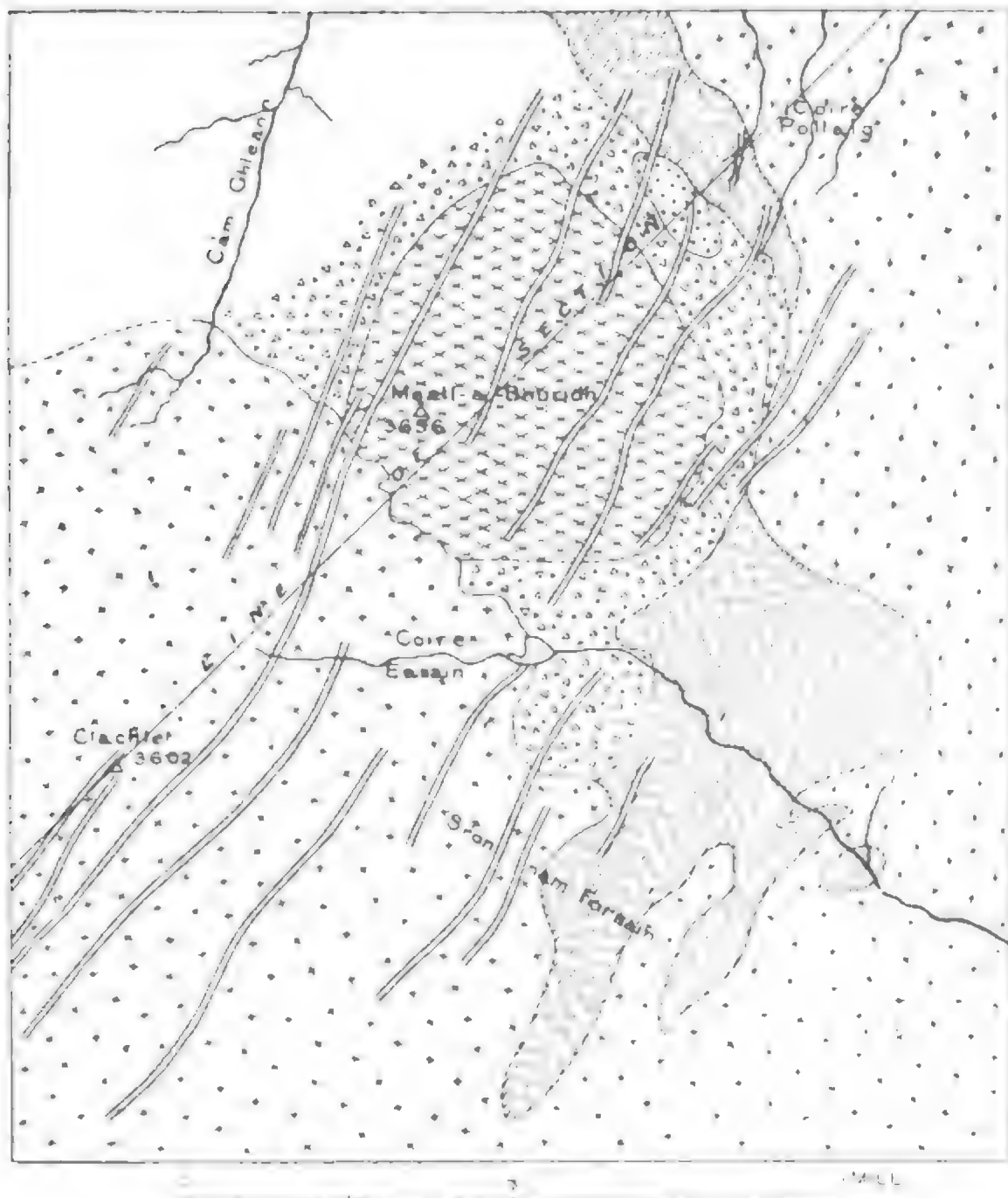
The Volcanic Rocks of the Blackmount.—During the survey of the north-eastern portion of the Blackmount deer forest, a series of interesting volcanic rocks has been mapped, which doubtless represent an extension of the volcanic area of Glen Coe—an area which, owing to the rugged and inaccessible nature of the mountainous tract where the volcanic rocks occur, has hitherto received very little attention from the hands of geologists.* It has been supposed that these rocks constitute outliers of andesite lava-flows of probably Lower Old Red Sandstone age. That there are true lava-flows in the Glen Coe area may well be the case, but so far as the work has proceeded in the Blackmount, no rock has been met with which MR. KYNASTON could confidently assert to represent part of a true subaërial flow. The detailed mapping of the area has, up to the present, only included a very small portion of the volcanic series, but it has brought to light facts of great interest and significance.

The volcanic rocks occupy a tract of exceedingly mountainous ground on the south-east side of Glen Etive, and from about 3 to 5 miles south-east of the head of Glencoe. The volcanic tract apparently forms a roughly oval area, elongated in a north-westerly and south-easterly direction, and extends from Sron Creise, the conspicuous spur of the northern ridge of the Clach Leathad, south-eastward across the rugged Cam Glen to the sharp east-and-west ridge of Meall a Bhuridh, 3 miles S.S.W. of Kingshouse. The rocks which constitute this tract fall into three well-marked divisions:—(1) *felsites (rhyolites)*, (2) *breccias and agglomerates*, (3) *hornblende - andesites*. This order represents that in which the rocks are frequently met with in proceeding from the margin into the central

* See Judd "On the Ancient Volcanoes of the Highlands." *Q.J.G.S.* vol. xxx., pp. 294, 295, and Teall, "British Petrography," pp. 287, 288.

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portion of the volcanic area. The field-evidence leads to the conclusion that these rocks constitute a large and complex volcanic plug or neck, and that they represent the site in this area of one, or perhaps two, vents of eruption. These vents are now filled up with enormous masses of agglomerate and breccia, rhyolitic felsites, and andesites; and, further, the mapping has brought out what seems to be a definite arrangement of these materials within the vent. At the margin lies an outer zone of rhyolitic felsites, which may however be sometimes absent, or it may graduate into a moderately fine-grained felsitic-breccia (*i.e.*, a felsite, or rhyolite, charged with angular fragments). Within the felsite we find massive and usually coarse breccia and agglomerate, which may occupy the entire outer zone when the felsite is absent. The agglomerate encloses at least two central plugs of massive andesite. The andesites and rhyolitic rocks are, petrologically, typical lavas, but in the field they do not appear to constitute outpourings that have flowed out over the surface; there is no reason, however, that they should not represent, from their plug-like mode of occurrence, the subterranean portions of lava-flows which reached and were spread out over the surface. The behaviour of these rocks was found to be exceedingly puzzling, as no sign could be found of dip or separate flow or intercalated tuffs, or any of the well-known phenomena of the lavas of western Argyll, such as might give a clue to the structure of the ground, on the supposition of their being outliers. The rhyolites are seen to tower up in huge vertical walls and precipices split by numerous intersecting joint-planes, which sometimes give the rock a rudely columnar appearance. The scenery formed by these flinty-textured masses cannot fail to impress everyone who has seen the remarkable and precipitous eastern face of Stob Dearg, the highest point (3,345 feet) of the Buchaille Etive Mor. The andesites again form similar features on the south side of the Meall-a-Bhuridh ridge and above the Glas Choire north of the Clachlet, but they are more apt to crumble away and form long slopes of scree and talus. Where structure, otherwise than jointing, can be observed, it is invariably *vertical* or almost so. The fluxion-banding of the rhyolites, which is often well marked, is vertical. Different varieties of andesite succeed one another in vertical bands, sometimes, as on Meall a Bhuridh, with vertical flow-banding. Vesicular structure is rare or altogether absent. The rocks traverse alike elevated ridges and deep glens in a manner which cannot be reconciled with the idea of outliers. But a study of the junction sections between the finer breccias and felsites and the surrounding quartzites seems to afford perhaps the most conclusive test of the nature and mode of occurrence of these volcanic masses. On the north-eastern slopes of Meall a Bhuridh some excellent junctions or contact-sections are exposed, where the lowermost crags of felsite and breccia stand out above the quartzites. At first sight these volcanic crags might appear to be resting *upon* the quartzites, but a closer examination shows that the felsites and



MAP AND SECTION OF CONTACT OF GRANITE AND VOLCANIC VENT,
BLACKMOUNT, ARGYLLSHIRE.

Mr. Kynaston.

felsitic breccias rest *vertically* against the quartzites and quartzose schists, the former being frequently crowded with quartzite and schistose fragments. The junction is like that of an intrusive rock, the volcanic rocks appearing to have been forced up through the schists. The felsite sometimes shows good flow-structure, which is vertical, at the contact. The foliation in the schists is here also vertical, but it is not normally so in this area. The felsite appears to graduate into the breccia by a gradual accretion of foreign fragments. Sometimes the schists are undisturbed, and the contact is remarkably clean and sharp, but often, again, they are extremely broken up, and indicate in a remarkable manner the shattering and rending force of the volcanic outbursts. In the former case the contact is usually with compact felsite, in the latter case with breccia.

In some cases the junction between the older rocks and the breccia, connected with the outer zone of the neck, is exceedingly complex. It may in these cases consist almost entirely of quartzite fragments, and it is difficult to separate it from the true quartzite. From normal apparently undisturbed quartzite we pass into shattered quartzite, and from this into quartzite-breccia, with a dark greyish, sometimes almost black, matrix, full of small quartz grains. This is well seen at the side of the burn in Coire-an-Easain, south of Meall a Bhuridh, where also veins and bands of the breccia pierce the quartzites in an intrusive manner.

The survey of the entire area of the neck is not yet completed, but the facts at present known from the mapping, and from traverses over the other part of the ground, show that the tract is probably of an elongated oval or elliptical form, the outer portions of which are occupied by felsites, breccias, and agglomerates, while the inner portion contains two plugs of andesite; one constituting the whole of the upper part of Meall a Bhuridh (3,636 feet), exposed to a vertical thickness of nearly 1,600 feet, and measuring over half-a-mile in diameter; the other being exposed for a distance of close upon a mile on the elevated ridge (3,600 feet) between Sron Creise and the Clach Leathad. These two plugs are separated mainly by agglomerate, though between the two there are evidences of one or two subordinate plugs of lava. Along its longer axis the entire neck measures at least two miles. To add to the complexity of these volcanic masses, a vast number of sills and dykes of porphyrite, with some of quartz-porphry, have cut through them in a general north-easterly and south-westerly direction, and these appear to increase in frequency in the central plugs of andesite. Furthermore, the granite of the Clach Leathad, which, as above stated, is an extension of that of Ben Cruachan, has invaded the neck in its south-western portion, and intrusive contact-sections may clearly be seen between it and the andesites and breccias of Meall a Bhuridh on the one hand, and the andesites of the ridge north of the Clach Leathad on the other. The granite has been intruded into these rocks, and frequently veins them. The contacts in

the field are clear and well-defined, and decided contact-alteration ^{Mr. Kynaston.} has been produced. This has been confirmed beyond all room for doubt by the study of a number of sections of both altered and unaltered rocks under the microscope.

With regard to the relation of the different kinds of rock in the neck to one another, the felsite or rhyolite, as already remarked, appears to graduate into the finer type of breccia, and one cannot draw any line between this material and the coarser breccias and agglomerates. There may, however, be some felsites which are intrusive in the agglomerates. No hard and fast line can be drawn between breccias consisting almost entirely of quartzite fragments and coarse agglomerates consisting mainly of fragments of felsite and andesite. In some places the breccia might be termed comparatively fine-grained, and is full of small fragments of quartzite and felsite, averaging half an inch in length or less, but more usually the main mass of the rock is a confused agglomeratic mixture of angular fragments of all sizes, consisting of quartzite, felsite, micaceous schist, with occasional pieces of andesite. The quartzite fragments are sometimes two yards or more in length. As we approach the andesite, the agglomerate becomes more and more andesitic, consisting mainly of andesite fragments, but not invariably so; sometimes, as on the south-east side of Meall a Bhuridh, the fragments become smaller and less abundant, until a kind of transition rock appears, which seems to be blended and inter-banded in a peculiar manner with the true andesite. The appearance is sometimes that of a passage, and sometimes that of a vertical intrusive junction, on the part of the andesite. At the junction the andesite is often exceedingly rich in derived quartz grains and fragments of quartzite. On Meall a Bhuridh more or less vertical bands of slightly varying types of andesite succeed one another as the ridge is followed from east to west. These bands appear, like the porphyrite dykes, to have here a N.N.E. and S.S.W. trend. Sometimes a thin layer of brecciated andesite is seen between two bands. Along the summit of the ridge the banding due to flow is vertical; at the west end, above the granite contact, it seems to dip steeply eastwards into the hill.

On the north side of Glen Etive large masses of rhyolitic rocks breccias, and agglomerates form the Buchaille Etive Mor, and mark apparently another large neck. Stob Dearg, the highest peak, appears to consist mainly of masses of a rhyolitic nature from base to summit; but the mapping has not been commenced yet in detail on this side of the glen. A traverse has shown the existence of several varieties of rock of rhyolitic affinities, of a compact flint-like texture, varying in colour from almost black through shades of purple and brown to a brick-red, often with a most perfect flow-structure, and usually showing small felspar phenocrysts, with occasionally quartz in addition. The red felsites forming the summit (hence its name, Stob Dearg—the red peak) present a striking appearance, broken and splintered by the action of the frost, and strewn over the surface in count-

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less sharp, angular fragments. Breccias and agglomerates are seen just below the summit, and throughout the greater portion of the big corrie on the south-west side.

MR. KYNASTON has made a study of the petrographical character of the Rhyolitic rocks, the Breccias and Agglomerates, and the Andesites. His results will appear in the Survey Memoirs. Space, however, may be found here for his account of the contact phenomena of this region, as these bear on the age of the granites.

The rocks that have been altered by the intrusion of the granite into the volcanic series comprise the andesites of the western and south-western slopes of Meall a Bhuridh, and of the ridge north of the Clach Leathad, with some of the finer-grained varieties of the breccias between them. Some of the rhyolitic rocks occur very near the granite at the east end of Meall a Bhuridh, but no marked signs of contact alteration have been observed in them. The alteration of the breccias has not yet been examined in detail. Some of the specimens examined were evidently complex rocks, consisting of a mixture of andesitic and more or less fragmental material rich in derived quartz. The fragments of quartzite in these rocks appear to be gradually losing their individuality; the sharp outline becomes indistinct, and under the microscope [9170] the fragments tend to become merged into the surrounding rock. The main mass of the section consists in part of a mosaic of quartz and felspar, throughout which are scattered numerous small biotite flakes, minute greenish grains (hornblende?), and magnetite, and in part of quartz grains in a fine brownish matrix. Other portions, again, break up into a mosaic of micropoikilitic felspar, in which the secondary minerals are embedded. Sometimes there is a marked parallel arrangement between the different materials, and sometimes the appearance of brecciation [9173]. In less altered specimens the andesitic portions retain their original structure [9172]. These rocks, then, are not true andesites, but mixtures of material of diverse origin, whose presence is perhaps rather to be expected at a main focus of volcanic activity.

In the *andesites* the commencing stages of alteration are seen at the west end of the Meall a Bhuridh ridge, and may be traced up to the granite contact. One of the most noticeable general features of these altered rocks is the invariable loss of the dark, almost velvety appearance of the unaltered fresh rock. The colour becomes pale grey and the rock loses its sharp angular fracture, presumably with the development of a more thoroughly holocrystalline structure. The brown hornblende, the first mineral to be attacked, is replaced by clusters of small biotite flakes, usually associated with aggregates of green hornblende and magnetite granules [9163, 9174]. At first the form of the original crystal is maintained, but it is completely lost in the later stages; frequently the replacing aggregate consists almost entirely of green hornblende, and, on the other hand, in the pyroxene-bearing varieties north of the Clach Leathad, the brown hornblende is replaced almost entirely by biotite, with a little

magnetite. In the commencing stages portions of the original unaltered hornblende may be seen surrounded by a thick cluster of biotite flakes, the whole with the characteristic form of the hornblende crystal [9179]. The felspar phenocrysts are usually marked by a peculiar cloudiness, but show a marked stability, and sometimes appear to maintain their individuality even at the actual contact [9169]. The microlites of the ground-mass become indistinct, and gradually the entire ground-mass becomes replaced by a clear granular mosaic [9171, 9174]. Sometimes a relatively coarse aggregate is seen of clear micropoikilitic felspar, in the more advanced stages [9176], while a profusion of small biotite flakes, often in aggregates, and frequently accompanied by green hornblende and granules of magnetite, lies scattered throughout. The green hornblende is sometimes in excess of the biotite [9177]. Grains of sphene occur at the actual contact [9176]. The pale greenish augite, when present, is replaced by a pale green hornblende, but shows far more stability than the phenocrysts of brown hornblende [9179]. At the contact the granite is fairly coarse and of an acid type. It sometimes sends small tongues into and encloses portions of the andesite [9169].

It has now been conclusively shown that the great granite mass which extends from Ben Cruachan to Kingshouse is of later date than the plugging up of the great necks of the Blackmount area, and there can be no reason to doubt that these latter are an extension of the volcanic series of Glencoe. The Glencoe rocks have for some time been regarded as of Lower Old Red Sandstone age; the survey of the Blackmount area, although at an early stage, tends to support this view. It might perhaps be urged that no true augite- or enstatite-andesites, such as are so characteristic of the Lorne basin, have been found among the Blackmount series, and that the whole of this latter series has a more acid tendency. But it must be remembered that it is an exceedingly common and characteristic feature in many volcanic districts for the materials of necks and plugs to be more acid than the lava-flows which are associated with them, and we know also that in the upper part of the Lorne series there are acid rocks allied to rhyolite, sometimes associated, as in Glen Nant, with hornblende-andesites.* Further, the tuffs of Lorne, which belong also to a high horizon, indicate the blowing to pieces of acid rocks, and frequently contain fragments of typical hornblende-andesites. It would not be surprising, therefore, to find plugs of the same age containing hornblende-andesites and felsites, since such plugging up of vents of eruption must necessarily succeed the latest subaërial outpourings and represent the final phase of the eruptive activity of a volcanic focus. In the agglomerates near Kilmelfort, mapped by MESSRS. PEACH and SYMES, MR. KYNASTON noticed many phenomena similar to those observed in the Blackmount. He has also recently collected evidence of the existence of a series of altered andesitic rocks on

* See *Summary of Progress* for 1897, p. 84.

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the eastern side of the Ben Cruachan range, which in many respects show a remarkable resemblance to the altered andesites of Meall a Bhuridh and the Clach Leathad ridge above described, and have a similar mode of occurrence. If the evidence of these rocks is to be relied upon, this fact would help, as it were, to bridge over the gap between the Lorne basin and the Blackmount.

Sills and Dykes.—In the area of the Blackmount numerous sills and dykes traverse the older schistose rocks, the volcanic series, and the granites. They comprise some quartz-porphyrines, a large assemblage of porphyrites, the small and more compact varieties of which are practically intrusive andesites, with an occasional diorite and camptonite. A good quartz-porphyry is seen cutting the felsites of Sron Creise. It shows crystals of orthoclase, plagioclase, quartz, and some chloritic pseudomorphs after biotite, in a cryptocrystalline matrix [9130]. The quartz often shows good crystal form, and only very slight magmatic corrosion. The porphyrites are especially abundant in the neighbourhood of the andesitic plugs. They resemble for the most part the porphyrite sills in the Ben Cruachan area. A sill of a very fresh and typical hornblende-porphyrite, seen at the top of Stob a Choire Odhair, shows under the microscope [9020] phenocrysts of clear plagioclase, often zoned and sometimes showing pericline twinning, fresh idiomorphic brown hornblende and biotite. Both the hornblende and biotite are occasionally enclosed in the felspar. Some pale green fibrous hornblende also occurs, which may possibly represent altered augite. Sphene, magnetite, and apatite are accessory. The ground-mass is microcrystalline, and consists of small plagioclases, small biotite flakes, with some interstitial quartz, and probably also some alkali felspar. The porphyrites invariably show a well-marked chilled edge, the marginal part being often almost black, and resembling an andesite, while the central portion may be of a brick-red colour. Specimens from the margin and centre of one of these sills were compared under the microscope. The central portion [9131] shows phenocrysts of hornblende, biotite, and plagioclase, in a ground-mass consisting mainly of smaller plagioclases and micropegmatite. Sphene and apatite are accessory. The margin of the same sill [9132] shows phenocrysts of the same minerals, but in a much fresher condition and with sharper crystal-outlines, in a brownish felsitic matrix, which under crossed nicols splits up into lighter and darker spots and patches, possibly representing a sub-microscopic stage in the development of the micropegmatite seen in the central portion. These sills evidently represent the dyke-phase of a hornblende-andesite magma. They resemble the hornblende-porphyrites of the Criffel area.

A rather unusual type of diorite is seen cutting the quartzites on the north side of Corrie Bà. It appears to consist [9133] mainly of plagioclase and hornblende. The former is for the most part idiomorphic, and the latter consists of two varieties—one reddish-brown and the other pale green. The brown horn-

blende occurs as relatively large patches which frequently enclose small idiomorphic feldspars in a poikilitic or ophitic manner. It is also frequently crowded with small opaque, rod-like inclusions, with a parallel arrangement. The green hornblende occurs in smaller crystals and grains, and occasionally appears to form a narrow border to portions of the brown hornblende and in crystalline continuity with it.

Reference may here be made to a *lamprophyre* sill that occurs among the quartzites on the hill slope above the Episcopal church in Glen Creran. The weathered face is seen to be thickly studded with quartzite fragments, and in places the rock is so full of these fragments as to become a breccia. The fragments are sometimes rounded, but more often angular. The margin of the sill is a mixture of breccia and shattered quartzite. Somewhat similar sills have been reported by MR. GRANT WILSON from Glen Orchy, and from Glen Suileag in the Loch Eil district.* The sill in Glen Creran only appears at the surface for about 100 yards, disappearing below the quartzites at either end. We are, perhaps, therefore, not far from its vertical limit, and possibly we may explain the abundance of fragments by supposing them to represent portions torn from the walls of the fissure at various levels, and carried onwards, floating on the lamprophyre magma, so that they would tend to accumulate towards the limit of its intrusion.

Carboniferous.

During the past year the areas of Carboniferous rocks which have been examined and mapped by the Geological Survey have lain in South Wales, North Staffordshire, and adjoining counties, and the Culm districts of Devonshire.

SOUTH WALES.†

Carboniferous Limestone.—This subdivision of the system has been mapped on the North Crop by MR. CANTRILL, and in Gower on the South Crop by MR. TIDDEMAN. It not only expands vastly in its passage southwards under the coal-field, but changes so completely in the detailed sequence of strata that no correlation of the two tracts is possible except as regards the upper and lower members. On the other hand, the sections observed by MR. CANTRILL correspond almost in detail with those described in previous Reports along the North Crop further east, while MR. TIDDEMAN is able to pick up in Gower some of the horizons with which he had become familiar in the neighbourhood of Bridgend. Further proof is thus afforded of the fact already made clear that the members of the Carboniferous system, though rapidly developing and changing character in a north to south direction, remain fairly uniform in an east to west direction. It may be assumed that the rocks were deposited

Messrs.
Strahan,
Tiddeman,
and Cantrill.

* *Summary of Progress* for 1897, p. 66.

† This section has been drawn up by MR. STRAHAN.

Messrs.
Strahan,
Tiddeman,
and Cantrill.

along a shore running east and west, at no great distance north of the present limit of the Carboniferous area.

In the North Crop MR. CANTRILL recognises the following divisions of the Limestone series, in descending order :—

Rottenstone Shales	-	{ Shales with thin black and impure Limestones decalcified at the outcrop, and worked for rottenstone, and with two or more thin bands of radiolarian chert.
Main Limestone	-	{ Dark Limestone with nodules of Black chert, devoid of radiolaria.
		{ Light-coloured Oolite, 30 to 40 feet.
		{ Dark Limestone and Oolite.
Lower Limestone Shales.		Shales with thin Limestones.

The Lower Limestone Shales are about 15 feet thick at Careg-yr-Ogof, the most northerly prolongation of the Limestone. Further west, at the sources of the Clydach, they are probably twice that thickness, and may there be seen to pass down into yellow sandy shales and sandstone, and so into the Grey Grits. On the Cennen they are about 34 feet thick.

Somewhat more than half of the Main Limestone consists of a dark rock, much of which is minutely oolitic. A thin band of corals some few feet above its base, which was first noticed east of Glyn Tawe, persists as far as the mapping has proceeded. Upon the top of the dark limestone comes a soft, fine-grained sandstone of a light-grey or yellow tint which weathers in the pitted manner characteristic of calcareous sandstones. It has evidently been a very sandy limestone. Though only about 10 feet thick, it has been traced almost continuously from Glyn Tawe westwards for about 12 miles. The sandstone is succeeded upwards by the light oolite, which always forms a conspicuous horizon about the middle of the limestone-crag. To the south-east of Trapp it is about 30 or 40 feet thick. It passes upwards through darker oolite containing many grains of sand, into dark thin-bedded limestone with nodules of black chert.

The Rottenstone Shales are of exceptional interest on account of the discovery in them of bands of radiolarian chert, as hereafter described. The series is thin and everywhere obscured by the *débris* of the Millstone Grit, but the outcrop is marked by an almost continuous line of old workings for the rottenstone, a residue of the thin black limestones after decalcification. The result of a microscopic examination of the chert by DR. HINDE is given below. Though radiolaria are not uncommon, sponge spicules predominate. The occurrence of these organisms suggests a deep-water origin, but the series is immediately overlain by the pebbly conglomerate which forms the base of the Millstone Grit. Wavellite occurs on the joint-faces of the harder bands.

In the south crop MR. TIDDEMAN finds evidence of a considerable development of the Lower Limestone Shales, though there are but few sections. The hamlet of Southgate is built on a splintery olive-brown shale in which fragmentary fossils occur, and there is a probable inlier near the village of Parkhill. The

varieties of limestone previously observed by MR. TIDDEMAN (Summary of Progress for 1899, pp. 111-112) persist in the ground recently surveyed. The pitted limestones of pseudo-brecciated type, which are noticed at Newton Nottage and Mumbles Head, have been found near Llefridd and further south at Oxwich, with intermediate exposures at Pwll-du Head and Bishopston. They keep to a definite horizon near the top of the Carboniferous Limestone, and obviously owe their breccia-like appearance to conditions of original deposition, and not to crushing, although dolomitisation has been at work subsequently. Where dolomitisation has not been set up, the chinks which meander through the rock may be better seen, and it is, then, obvious that they do not follow planes, as would be the case with jointing or fractures from crushing, but wander about like the lines in a puzzle. The component pieces have been subjected to some force acting round separate centres, as in the formation of nodules, and the several spheres of influence have become irregularly crowded together at the periphery, thus producing the curious fissures which bound them. These have in most parts been paths for dolomitic action, and so the centres stand out like angular and rounded fragments, and look at first sight like those of breccias or conglomerates.

Messrs.
Strahan,
Tiddeman,
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The Upper Limestone Shales, which made their first, or most easterly, appearance near Penwyllt, in the North Crop,* have now been definitely recognised in the South Crop in Gower. A cutting on the road from Clyne Common to Bishopston forms the only section known at present, though clay was formerly dug from the outcrop of the shales near Newton. East of Swansea the series is unknown. It would seem, therefore, that while in both the North and South Crop the Upper Limestone Shales make their appearance in a westward direction, they come in somewhat later on the south side, or, in other words, that the eastern margin of their area of deposition runs in a south-westerly direction.

So long ago as 1846 these Bishopston strata received the close attention of DE LA BECHE.† He not only measured a detailed section‡ through some 1,600 feet of the strata lying next above the massive Carboniferous Limestone, and sketched the distribution of the series, but instituted a careful comparison of the Gower sequence with that of North Devon. He pointed out that the Gower series generally resembles the strata which graduate down into the Pilton group, and made special reference to certain whitish, grey, and black shales, in thin beds, intermingled with white arenaceous and argillaceous layers, noticed by PROF. PHILLIPS at Coddon Hill. The siliceous bands in the Coddon Hill strata had long been known to contain wavellite in the joints, and DE LA BECHE, without laying much

* *Summary of Progress* for 1898, p. 112.

† *Memoirs of the Geological Survey*, vol. i., pp. 133-134.

‡ The section is believed by MR. TIDDEMAN to have been measured along a cut for a mill-race now disused and overgrown.

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stress on the fact, regarded it as interesting that the same mineral occurred under supposed similar geological conditions in Gower. These Coddon Hill beds, which had hitherto been regarded as arenaceous and cherty sediments, were proved in 1895 by DR. G. J. HINDE and MR. HOWARD FOX,* to be rocks of organic origin, consisting, to a great extent, of radiolaria, and forming one of the largest deposits of such remains hitherto known. Under these circumstances it was recognised that the detection of radiolaria in South Wales would possess the greatest interest as being likely to confirm the comparison instituted by DE LA BECHE, and to assist in the extremely difficult co-relation of the strata on the two sides of the Bristol Channel. Accordingly search was made, and met with immediate success, both in the North and South Crops. Sufficient proof has been obtained that the Coddon Hill Series, the Gower Series, and the Rottenstone Beds are strictly correlative deposits.

As described by MR. TIDDEMAN, the road in which the section occurs, between Clyne Common and Bishopston, runs parallel to the top of the uppermost massive limestone for about 500 yards. The rock is oolitic but dolomitised in places, and dips at 50 or 60 deg. to the N.N.E. The strata cut through by the road are somewhat crumpled. They consist in their lower part of at least 30 feet of white and yellow clays. Above these lie about 15 feet of more distinctly bedded clays, hard and soft, with irregular thin seams of limestone and chert; they contain wavellite (a hydrous phosphate of alumina) in small discs of radiating crystals in the joints of the harder bands, and yield a characteristic Carboniferous Limestone fauna. The following specimens have been identified by MR. E. T. NEWTON and Dr. F. L. KITCHIN from the rottenstone below the radiolarian cherts—

Crinoid stem ossicles (mould); *Fenestella* sp.; Polyzoon; *Chonetes*?; *Orthis* sp.; *Productus* (fragment of small valve); *Rhynchonella*?; *Spirifera trigonalis*? Mart.; *Spirifera*?; *Spiriferina cf. cristata*, Schloth; *Cythere*?; *Griffithides* (fragment of head-shield); *Phillipsia*? (pygidium).

The cherts in this series are silicified limestones, and contain a large foraminifer (cf. *Nummulina pristina*, Brady), sponge-spicules (decomposed), fragments of echinoderm plates and *Dentalium*? At the top of this group some thin black cherts occur, which are distinguished by showing white streaks, more or less lenticular. The resemblance of these banded cherts to the radiolarian chert of Coddon Hill was obvious, and a typical specimen was collected by MR. WOODWARD during a visit to the spot with MR. STRAHAN and MR. TIDDEMAN, in order that it might be examined under the microscope. The specimen was pronounced by DR. HINDE to be a typical example of the Culm Radiolarian Chert, and to resemble very closely the Devonshire culm cherts.

A few days after this specimen was obtained the outcrop of the Rottenstone beds on the north side of the Coal Field was visited by MR. STRAHAN and MR. CANTRILL, and specimens of

* *Quart. Journ. Geol. Soc.*, vol. li., p. 609.

banded chert, which had been noted by the latter, were collected at Careg Dwfán, there being reason to believe both from their appearance and stratigraphical position that they would correspond to those of Gower. Slices from the cherts of both districts were submitted to DR. G. J. HINDE, to whose kindness we are indebted for the following report :—

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“A. CARMARTHENSHIRE. [North side of Coal Field.] Nos. E 3306, 3309, 3311-3314 are of the same character—dark cherts with lighter decayed portions. They mainly consist of casts of detached sponge-spicules and casts of Radiolaria, both organisms very faintly shown. The Radiolaria are, for the most part, simple circular and oval forms, probably belonging to *Cenosphaera* and *Cenellipsis*; only the outlines bounded by matrix, as a rule, are now preserved; in some instances, however, perforations in a wall can be seen. Oval forms with radial spines are rare.

“The sponge-spicules are apparently minute simple acerates, but with these four- or six-rayed spicules of hexactinellid sponges are occasionally present. It is possible that some of the needle-like spicules may be the broken off radial spines of radiolaria. The greater portion of the chert is evidently a mass of minute spicules or spines of siliceous sponges, with possibly some radiolarian spines; with these are commingled some radiolarian casts, but they are, relatively, in smaller proportions than the spicules.

“B. GLAMORGANSHIRE.—Nos. 3334, 3337-3341, Bishopston road-cutting, and Nos. 3328-3331 road from Newton to Clyne Common. [Collected by MR. TIDDEMAN.] These are hard black cherts with even horizontal bands of lighter tints. They all show numerous circular and oval casts of Radiolaria as clear spaces in a dark matrix. The casts for the most part are without walls or structure, but in some there are distinct spokes, radiating from an inner central sphere. They belong to *Cenosphaera*, *Carposphaera* and *Cenellipsis*. In addition the rock contains three-rayed spicules of the radiolarian genus *Sphaerozoum*. Sponge spicules, also as casts, some hexactinellid, are likewise present, but subordinate in number to the Radiolaria. The specimens are typical radiolarian cherts.

“The character of the rock, the mode of preservation of the radiolaria, and the forms themselves are very similar to what are found in the cherts with Radiolaria from the Lower Culm of Devon and Cornwall described by HINDE and Fox (*Quart. Journ. Geol. Soc.*, vol. li., 1895), and two of the Radiolaria showing structure, *Porodiscus* and *Carposphaera*, are identical species with those figured in the Culm chert (*op. cit.*, Pl. xxv., figs. 6, 7; Pl. xxvii., fig. 1). The *Sphaerozoum* spicules (Pl. xxv., figs. 1e, 1f, 1g.), also correspond closely with those from the Culm. This, resemblance to forms from the Lower Culm chert is more strongly marked in the chert specimens from Gower; the Radiolaria from Carmarthenshire are, as a rule, distinctly smaller and, as already mentioned, they occur in a rock in which sponge spicules predominate, whereas in the Glamorgan chert the prevailing facies is unmistakably Radiolarian.”*

* From a letter by DR. GEORGE J. HINDE, F.R.S., dated Dec. 18th, 1900.

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Continuing the examination of the series in an ascending direction, MR. TIDDEMAN finds that the clays give way to much chert, mostly black, and not banded, associated with hard cherty shale, the whole being only a few feet thick. These cherty strata in his opinion, mark the upward limit of the usual Carboniferous Limestone fauna; above them there occurs a thick mass of black or bluish ferruginous shales, all dipping at a high angle and occupying a belt of ground about 1,000 yards wide. It may be inferred that they are thick, and, in fact, DE LA BECHE's section shows more than 1,590 feet above the cherty zone, but the mapping of the region is not sufficiently advanced to enable us say whether or not there is repetition. *Glyphioceras bilingue*, Salt. which is described and figured under the name of *Goniatites bilinguis* by SALTER,* occurs abundantly in some bands, and *Posidonomya* has been observed by MR. TIDDEMAN. The *Glyphioceras* is a common shell in the Millstone Grit shales of Yorkshire, Lancashire, and Derbyshire.

Millstone Grit.—As already mentioned, the summits of the Black Mountains are formed by the basal conglomerate of the Millstone Grit west of the point at which the hard conglomeratic beds at the top of the red sandstone subdivision of the Old Red series disappear. One of the finest exhibitions of the rock is furnished by the faulted promontory of Gareg-lâs, but westwards the conglomerate is disintegrated. At several points there is a notable absence of pebbles, and at Pen-rhiw-wen soft grit beds are dug for "silica-sand."

The breadth of outcrop presented by the grit west of the Neath and Llangadock road is maintained in spite of an increase of dip, owing to the influence of a well-marked roll which traverses the district between the Amman and the Cennen in a general E.N.E. direction. The ridge of Tair Carn marks an anticline, while the upper part of the valley of the Llwehwr follows a parallel syncline, by which the middle or shaly portion of the Millstone Grit is introduced. This belt of folding runs parallel to and about six miles north-west of the Cribarth disturbance. The sandstones and shales which constitute the upper part of the Millstone Grit form dip-slopes on the moorlands north of the Amman Valley and are well exposed in Cwm Garw.

Coal Measures.—The surveying of the Coal Measures during the past year has been carried on chiefly between the Tawe and Loughor Valleys, in an area of somewhat complex structure. In a general way the structural features resemble those of other parts of the coal-field, for the measures dip steeply along the South Crop, but rise gently towards the North Crop. The syncline thus produced, however, not only includes minor east and west folds, but is broken across by powerful faults ranging partly in the normal north-north-west direction, and partly

* *Mem. Geol. Surv.* Geology of the Country around Oldham, p. 60.

in a direction somewhat east of north and approximately parallel to the Vale of Neath and Cribarth Disturbances.*

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Of the minor east and west folds referred to, one runs from near Forest-fach westwards along the valley of the Afon Llan. It includes a syncline by which a trough of the Four-feet Seam has been thrown in, and a sharp but local anticline which has been proved to the north of the syncline, at Forest-fach. Another minor syncline runs under Rhyd-y-Pandy to Bryn Whilach, where it was found in working the Four-feet Seam. At that point it appears to turn westwards, and to pass under Tyle-du. There are therefore two distinct troughs of the Four-feet Seam and the measures above it, that is, of the uppermost existing measures of South Wales, which have been referred to in previous Reports as the Llantwit or Mynyddislwyn Measures. To the east of the Tawe, on the other hand, these minor folds have ceased to exist, and the main syncline of the Coal Field has lost its compound character.

The most conspicuous of the other structural features referred to are the north-north-westerly faults which succeed one another with monotonous regularity. Most of them are downthrows to the west, but the Pwll-mawr Fault is a downthrow to the east of 80 yards at the Colliery of that name, and of no less than 130 yards at the Pen-rhiw-felen Colliery. Two of the faults, moreover, have been proved to change the direction of downthrow. One of them known as the Cwm Pit Fault is a downthrow to the west of 44 yards, but about half a mile further north ceases to shift the strata. In the same line, however, a few yards farther on, a fault commences with a small downthrow to the east which increases to 22 yards at Llangyfelach. The second case is that of John Grey's Fault, which is a downthrow to the west, of 178 yards, north of Cefn Cadle. Near Mynydd Newydd Colliery the throw is almost *nil*, while south of the colliery a fault in the same line throws the strata down to the east.

The third type of disturbance recognised in the Swansea district is represented by two deep faulted hollows, the one concealed under the alluvium of the Tawe between Clydach and Morriston, and the other running near Melin Cadle between the workings near Forest-fach and those at Carngoch. The first named has been, to a great extent, explored, and has been proved to run somewhat east of north; the other is in process of being proved, and so far as the evidence goes, must have much the same direction. While distinct from the north-north-westerly system, these disturbances do not link themselves on to the east and west folds which plicate the strata in Gower. If, therefore, as seems probable, they belong to the same system as the Vale of Neath and Cribarth Disturbances, they indicate that a distinction exists between these disturbances and the plications of Gower and the Vale of Glamorgan, of which the pre-triassic age is so beautifully shown in Barry and Sully Islands.

* Described in the *Summary of Progress* for 1898, pp. 117-119.

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The seams which have yielded nearly all the coal worked near Swansea lie high in or above the Pennant series, the highest existent being those which have been let down in the deep faulted hollows of the Tawe Valley and Melin Cadle. The Four-foot seam (as explained in the *Summary of Progress* for 1899, pp. 120, 121) is believed to be the Llantwit No. 1 or Mynydd-islwyn Seam, and as in the more eastern part of the Coal Field, the measures above it are generally soft. Above the Five-foot seam, on the other hand, there is a thick strong sandstone, which makes its presence known by such bold features as the crest of the hill above Morriston. A still stronger rock above the Graigola or Six-foot Vein gives rise to a subsidiary ridge running parallel to and on the north side of the main Pennant escarpment, and forms also broad tracts of mountain-land along the north crop of that vein. The following table gives the distances proved around Swansea and forms a continuation of the table given in the *Summary* for 1899, p. 121.

Table of Distances in Yards between the Principal Seams near and West of Swansea.

	Gorseinon.	Carn Goch.	Mynydd Newydd.	Penrhiwfelen.	Pentre Pit and Borehole.	Calland's Pit.	Mansel and Graig.	Llansamlet.
Drews vein -	-	-	-	-	-	-	-	-
Measures -	-	-	-	-	-	-	-	165
Four-feet vein	-	-	-	-	-	-	-	-
Measures -	118	115	-	-	-	-	-	118
Five-feet vein	-	-	-	-	-	-	-	-
Measures -	-	-	-	-	-	-	-	-
Jenkin vein -	133	-	141	139	-	-	-	118
Measures -	-	-	-	-	44	55	52	-
Six-feet vein	-	-	-	-	-	-	-	-
Measures -	22	-	12	13	18	16	13	20
Three-feet vein	-	-	-	-	-	-	-	-
Measures -	-	-	-	-	38	38	49	44
Two-feet vein	-	-	-	-	-	-	-	-
Measures -	-	-	-	-	200	-	202	-
Slatog vein -	-	-	-	-	-	-	-	-
Measures -	-	-	-	-	-	-	24	-
Curly vein -	-	-	-	-	-	-	-	271
Measures -	-	-	-	-	49	-	22	-
Bodwr vein -	-	-	-	-	-	-	-	-
Measures -	-	-	-	-	-	-	12	-
Hughes vein	-	-	-	-	-	-	-	-

All of the measurements given in this table were made in shafts sunk through nearly horizontal strata, with the exception of the Mansel and Graig Colleries, where they were taken by MR. W. MORGAN in a cross-measure drift through strata dipping at 32 deg. In the Pentre section the strata were proved from the Two-feet Vein downwards in a borehole, and the Llansamlet

section is made up from various sources, no one shaft having proved the whole sequence. It will be seen that the thicknesses remain fairly constant from Swansea westwards, and that the seams are identifiable without difficulty. With respect to the correlation with the Neath trough,* one point may be added; a small seam, known as the Morris Vein east of the Tawe, and as the Jenkin Vein west of the river, occurs about 50 yards above the Graigola or Six-feet Vein, and may represent the Tyr Edmond Vein of Skewen, though it lies rather higher than might have been expected.†

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The group of veins of which the Hughes is the most important, forms the base of the productive Swansea Coal Field, the seams lower in the Pennant being unimportant, while those at or below the base of that rock crop out under houses or in the foreshore, and are difficult of access. The Hughes group crops out along the north foot of the ridge of highly inclined Pennant which includes Kilvey and Town Hills and trends thence past Dunvant. The following estimate of the thickness of the grits below the Hughes group is approximate only, and may require modification as the examination of the ground proceeds:—

Descending Section near Swansea.

	Yards.
HUGHES (or WENALLT) VEIN—	
Measures, chiefly sandstone in the upper part as seen in the Cwm-bwrla Quarries - - - - -	267
CUCKOO or WAINWEN VEIN—	
Measures, chiefly sandstone as seen in the Baptistswell Quarries and on the summit of Kilvey Hill - - -	217
DYVATTY VEIN, or supposed No. 2 RHONDDA—	
Measures, chiefly sandstone as seen in the Graig Quarries and on the southern face of Kilvey Hill, but with one or more thick beds of shale - - -	183
TOR MYNYDD VEIN—	

On comparing these estimates with those made in the Neath valley‡ we find a distance of 484 yards between the Hughes Vein and the supposed No. 2 Rhondda as compared with 420–440 yards, an increase in a southerly and westerly direction such as might have been expected.

The Cuckoo Vein, an unimportant seam in the middle of the main mass of Pennant Grit, is said to have been proved at Pen-y-graig. The Dyvatty Vein was formerly worked by a level near the Cattle Market and at the Workhouse. Six hundred

* *Summary of Progress* for 1899, p. 121.

† Opportunity may be taken here to correct two errors in the figures given in the *Summary of Progress* for 1899. On p. 120, the distance between the Wernffraith and Graigola Veins should be 254 yards and not 454 yards as printed. On p. 122 the throw of the Rhydding Fault at Cwru Clic should be given as about 580 yards instead of 340 yards.

‡ *Summary of Progress* for 1899, p. 118.

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yards west of the Workhouse there seems to be an upthrow to the west, for what appears to be the same vein has been worked in the quarries above Terrace Road, too high up for the crop proved at the Workhouse.

The measures below the Dyvatty Vein are partly shown in the Graig Quarries. Though including thick beds of shale, they consist chiefly of sandstone indistinguishable from the Pennant rock above the Dyvatty Vein. This rock presumably corresponds to the Llynfi or Tor Mynydd rock mapped by MR. TIDDEMAN further east. The Tor Mynydd Vein probably crops out below this rock, at the foot of the steep declivity along which Underhill Street is built. The lower Coal Series may be inferred to crop out under the gravel on which the lower part of Swansea is built and in the foreshore. A clue to its position may be furnished by the outcrop in Gower, in ground not yet surveyed.

The North Crop presents a marked difference to the South Crop in this part of the Coal-field in the Coal Measures, as in all the other members of the Carboniferous System. Not only do the measures decrease in thickness northwards, but the seams deteriorate or even dwindle away in that direction. Thus the Four-feet Seam, though it proved well as far north as Bryn Whilach, has not yet been definitely recognised at its north crop. The Five-feet Seam has been extensively worked around Morriston, but proved worthless near Clydach. It is worked at Carn Goch and proves well at Gorseinon, but is not known as a workable seam at its northern outcrop; under the name of the Greenway Seam it is workable at Skewen, but dwindles away under Mynydd Drumau. We can therefore define the northern limit of deposition of this seam in a workable form as a line drawn east and west through Mynydd Drumau, near Clydach, and thence westwards. The Six-feet, or Graigola Vein, on the other hand, is more persistent, and its northern crop may be traced step by step by an almost continuous line of old workings, though this seam also proved worthless under Banc Maes-tir-Mawr, apparently in consequence of a local "wash-out." The Three-feet and Two-feet veins, though of great value at Llansamlet and Landore, are worthless, though recognisable, in the Clydach Valley and on Mynydd y Gwair, and are unknown along the remainder of their north crop. The Hughes group again seems to be represented by one seam only at its northern rise in the Tawe Valley; at Graig-tre-banos there are two seams, a few yards apart, on this horizon, which are said, however, to be inferior and very sulphurous, while to the west of the Clydach Valley the group has not yet been recognised, unless it be represented by some thin coals in Cwm Cathan in ground not yet examined.

On the North Crop MR. CANTRILL commenced the examination of the lower coals and ironstones. They were formerly worked by patch-works at Brynamman, and they run thence along the south side of the Amman Valley. The next important coal above, known as the Red Vein, is separated from them by a considerable thickness of barren measures, and crops out at the

foot of the high ground. It ranges from a little over 3 feet, at Gwaun-cae-gurwen, to 4 or 4½ feet at Cwm Gors and Cawdor collieries. Messrs. Strahan, Tiddeman, and Cantrill.

Above the Red Vein there are several unimportant seams generally overlain by sandstones resembling Pennant, and associated with bands of grey quartz-grit. These veins are worked to a small extent along the crops on Penlle'r-fedwen and Mynydd Gwrhyd. One of them is distinguished by the character of its roof, which is a coarse Pennant grit, containing ironstone-nodules, quartz-pebbles, and fragments of carbonised plants. It can be traced from the Bryn Llefrith Fault at Pen-rhiw-fawr south-westwards into Cwm-y-Gors, and so far as can be judged, occurs at about the same horizon as the Ynys-arwed Vein of the district east of the fault. The occurrence of a conglomeratic roof has been referred to as a characteristic of the Ynys-arwed Vein,* and it has also been pointed out that that vein represents the No. 2 Rhondda Seam. We are able, therefore, with some probability, to identify in the North Crop the equivalent of the Dyvatty Vein of the South Crop. There are indications, however, that both on the north and south sides of the coal-field this vein is becoming impersistent.

The rapidity of the change from bituminous coal to anthracite constitutes a most important feature in the seams of this part of the Coal-field. On the South Crop all are bituminous. Towards the centre of the field the uppermost seams still maintain a bituminous character, but the Six-feet and those below it have passed into the condition of steam-coals; and so rapidly that coal of a totally different quality may be obtained from the same vein in the workings of the same colliery. In the North Crop all the veins are anthracitic. Though the veins all become less bituminous northwards, the deeper veins are the first to change, so that in any one sinking the higher coals are always more bituminous than those at a depth.

No connection appears to exist between the anthracitisation and the structure of the ground; nor, on the other hand, is there evidence of the anthracitic region having been more deeply buried than the bituminous; on the contrary, the measures are far thicker along the bituminous South Crop than in the anthracitic North Crop. The phenomena point rather to the anthracitisation being a form of regional metamorphism.

Faults and Disturbances.—(1.) *North Crop.*—Of the numerous faults traced by MR. CANTRILL in the Lower Carboniferous Rocks of the North Crop one only has been found to extend southwards through the Coal Field—namely, that which is known in various parts of its course as the Cwm Llynfell, Bryn Llefrith, or Rhydding Fault.†

The Twrch Fechan Fault throws the middle shales of the Millstone Grit against the Basement Conglomerate on Llorfa, and forms the eastern boundary of the Millstone Grit of

* *Summary of Progress for 1899*, . 117. † *Ibid.*, pp. 122, 123.

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Gareglâs for about a mile, after which it breaks up and ceases to be recognisable in the Old Red Sandstone. It has a downthrow to the west.

A fault, skirting the western side of the Twrch Valley throws Millstone Grit against limestone, and forms the western boundary of Gareglâs. Its downthrow is to the east.

The Cwm Llynfell, or Bryn Llefrith Fault runs along the eastern side of Mynydd Gwrhyd, throwing down the Pennant rocks of that hill on the west against the Red Vein on the east. At Cwm Llynfell its throw has been calculated on the following evidence. A shaft, commencing almost on a level with the crop of the vein, but on the opposite side of the fault, proved the Little Vein at twenty yards depth. The true distance between the Red and Little Veins is about 210 yards, which indicates that the throw of the fault is about 180 or 190 yards, rather less than was stated in the *Summary of Progress* for 1899, p. 117. The fault then skirts the western side of Gareglâs, where it throws the middle shales against the Basement Conglomerate of the Millstone Grit, and crosses the escarpment at Pen-rhiw-wen, with a throw exceeding 100 yards. In the Old Red Sandstone its course is obscure. Its downthrow is to the west.

A fault with a throw of only twelve yards in the lower veins at Brynamman crosses the Black Mountains to Nant Oesglyn. Its throw in the limestone appears to exceed 200 yards. It has a downthrow to the west.

A fault commencing in the Pedol Valley crosses the ridge of Tair Carn and dislocates the base of the limestone at Blaen Cennen. Downthrow to the east.

(2.) *In the Coal Field.*—Allusion has been made to the fact that the disturbances near Swansea fall into three groups—namely, the great synclinal and anticlinal folds, which run approximately east and west, and which are of pre-Triassic age; the north-north-west system of normal faults, which are believed to be, in part at least, of a much later age; and, thirdly, some deep-faulted troughs, which nearly agree in direction with the Vale of Neath and Cribarth Disturbances,* and of which the age is doubtful.

The east and west folds are exemplified by the broad compound syncline previously described as throwing in two fields of the Four-feet Vein between the Tawe and the Loughor; by the steep upturn of the measures of the South Crop; and by the sharp plications of the limestone of Gower.

The north-north-westerly system includes the following in consecutive order from east to west:—

The Gardener's Fault was traced as far north as Glais in the *Summary of Progress* for 1899, p. 123. It then seems to make a slight bend to the west in crossing the Tawe Valley, as was the case with the Dyffryn and Rhydding Faults, and to run between tracts of the Hughes' Seam at Craig-tre-banos and of the Graigola Seam of Cathelyd. Though it has not been reached in the work-

* *Summary of Progress* for 1898, pp. 116–119.

ings of either, the evidence at the surface points to its running a few yards west of Gellionen Farmhouse. Thence it presumably follows a hollow leading by Allt-y-Fanog, and skirts the western slopes of Carn Llecharth, where the form of the ground and lines of springs suggest a line of fault. It is evidently dying out northwards; its downthrow is to the west.

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The Bethel Fault, which was believed to have been reached in the southern workings from the Garth Pit, is probably continuous with one of 60 yards throw proved at Bwllfa. The same line of dislocation continues by Fagwyr and along the western side of Mynydd-y-Gwair, where its shift of the outcrop of the Graigola Vein is recognisable, though small; downthrow west.

A fault on the west side of Mynydd Gelli-Wastad has been proved to have a throw of more than 55 yards. It runs under Glyn-collen, and is nearly in the line of the Six Pit Fault; downthrow west.

Several faults with throws ranging from 4 to more than 30 yards have been proved in the Six-feet (Graigola) workings near Rhos Fawr. All these have downthrows to the west.

A fault runs under Pentre Poeth and Cwm-rhyd-y-cwrw and is believed to continue thence by Maes-gwernen to the old Maes-tir-mawr shaft, where it divides, one branch running along the valley to Daren Fawr, while the other ranges across the mountain to near Rhyd-y-gelli-fawr. At Pentre Poeth this fault has been encountered in the Four-feet Vein, which lies at a shallow depth on its eastern side; on its western side this vein has been found in one place only, namely, in an exploration from the Pen-rhiw-felen Colliery, although trials have been made for it in other places; downthrow to the west.

The Maes-y-gelynen Fault is a continuation of the Pwll-mawr Fault.* It has been encountered in the Six-feet and Three-feet workings under Morriston, and was proved in the exploration at the Pen-rhiw-felen Colliery just referred to. A drift was carried through the fault from the Five-feet workings, and a borehole was put down, which proved the Four-feet Seam with the Two-feet† below it, at a depth of 9 yards. The throw of the fault is, therefore, about 130 yards, as compared with 80 yards at Pwll-mawr. Its course northwards is wholly unknown. It has a downthrow to the east.

The Cwm Pit Fault has already been noticed. It has a downthrow to the west, which changes northwards into a downthrow to the east.

The Cae Parc Fault has a throw of 22 yards near Tre-boeth, but dies out a mile to the north. Downthrow east.

John. Grey's Fault has been mentioned previously as an example of a change of throw. That it is a downthrow to the east, south of Mynydd Newydd Colliery, was proved in a drift

* *Summary of Progress* for 1899, p. 124.

† Not the Two-feet Vein of Llansamlet, but a vein lying 4 or 5 yards below the Four-feet.

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from Pentre, which passed from the Six-feet Vein on the east side into measures below the Two-feet Vein on the west side; at the Colliery its throw is very small, while 84 chains northwards it has a downthrow to the west, of 178 yards.

The Pwll-yr-hywaid Fault has been met in the Five- and Six-feet workings from Mynydd Newydd, but not crossed. If, as there is some reason to believe, the Four-feet Vein is near the surface on the west side of the fault, the throw would not be large, but explorations are now proceeding; downthrow east.

The Penlle'r-brain Fault was proved in the Five-feet workings from Worcester Colliery to exceed 80 yards, and is supposed to be about 220 yards. A trial-pit near Kent on the west side of the fault was sunk 150 yards without proving the Four-feet Vein, although, as already mentioned, that vein may be near the surface on the east side of the fault. Further to the south-east the fault was proved in old workings in the Six-, Three-, and Two-feet Veins, but to the north-west its course is still unknown. So far the evidence points to its dying out rapidly, for though its throw is large as far as Cadle, it seems scarcely to shift the strata near Bryn-rhos. Its downthrow is to the west.

The next fault to be described has been proved in the Six-feet and Five-feet workings from Gorseinon and Carn-gôch Collieries to have a downthrow of 67 yards to the west. It runs along the foot of the Bryn-Dafydd hill to the west of the Pen-y-cwâr, and though its exact position under the alluvial meadows of Bach-y-gwreiddyn is unknown, its course by Allt-y-graban-fawr, the Bolgoed quarries, and thence across the Dulais, is clearly marked by an almost continuous bank of sandstone on its eastern or upthrow side. Nearly south of Bryn-Dafydd the fault has been proved to take a turn to the south-east, as though it were tending to run into the Penlle'r-brain Fault, but the ground between Bryn-Dafydd and Cadle shows evidence of a strong disturbance, as described below, and its structure has not yet been mastered in detail; downthrow to the west. Much assistance in the determination of this and other faults near Swansea, was given by Mr. THOMAS RICHARDS.

The third type of disturbance referred to is illustrated by two cases:—

The Tir Canol Fault is the name given to a deep faulted syncline, which runs under the alluvial flat of the Tawe from near Morriston to Clydach. The Four-feet Seam, which crops out a few yards north of the Marsh Pit, is about 18 yards deep at the Herring Pit (near Wychtree Bridge), and about the same depth at Tir Canol Pit. It crops out again near Carn-felin-fach, at the old Ynys-forgan slope, and presumably would be found cropping under the gravel near Garth Farm. These localities mark the southern and western margins of a deep trough, for the vein was worked at about 200 yards depth under Upper Forest Works; it dipped steeply down to S.E. towards the river at Ynys-forgan and Ynys-penllwch, and lay at a depth of 204 yards at Garth Pit. The trough thus defined follows the western edge of the alluvial flat pretty closely, and runs about N. 40° E

A strong south-easterly dip is apparently the main factor in defining this edge, but it was found in working the Four-feet Vein that the high dip was accompanied by a series of step-faults down to the south-east; the name of Tir Canol Fault thus came to be applied to the disturbed belt, and it was credited with a throw of more than 200 yards. The sharp antiline which traverses Mynydd Gelli-Wastad, and the Cathelyd syncline north of it, seems to be part of the Tir Canol Disturbance; downthrow south-east.

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A powerful disturbance, apparently of the same character, is believed to run from the neighbourhood of Cadle in a north-north-easterly direction. The examination of the ground is not yet completed, but the facts are as follows. The Five-feet seam has been worked north-westwards from Mynydd-Newydd to the Pwll-yr-hwyaid Fault, where it lies at a depth of about 122 yards. The dip being to the north-west, the Four-feet Vein should "take ground" at this spot, and no doubt does so under the swampy land between Blaen-y-maes and Glyn-siling. The Pwll-yr-hwyaid Fault being a downthrow to the east, the Four-feet Vein would come in somewhat further on its west side, and, as a matter of fact, there are some old levels north-east of Melin Cadle in a seam which is said to be 2 feet 6 inches thick, and which may be the Four-feet Vein. Further to the north at Tir-dwncyn the Cefn-gyfelach Company have worked the Five-feet Vein up to the John Grey's Fault, and have found reason to conclude that the Four-feet seam will lie at a depth of 40 yards, near Tir-dwncyn, where they have commenced sinking. North of this point we enter a tract deeply overspread with gravel and Boulder Clay, the bottom of which has not been reached. All along this east side of the Llan Valley the dip is in a general north-west direction, and it might be anticipated that the Four-feet Vein would be present under the valley and to the west of it.

On the west side of the River Llan a broad plateau of sandstone extends from Bryn-Dafydd to Melin Llan, the outcropping edge forming a bold and almost continuous escarpment. The Five- and Six-feet Veins are being worked below this sandstone, and it can be easily proved by a consideration of their depth that the rock lies immediately below the Four-feet seam. Accordingly, at Melin Llan, where the upper surface of the sandstone comes down to the river, we find resting upon it two somewhat inferior seams, which are no doubt the Four-Foot and a rider. These crops run down by Gorseinon Common to the Pen-y-cwâr Fault, to the west of which both have been proved and the rider has been worked. In addition to this a very small tract of the Four-Foot seam has been faulted in, 500 yards north-west of Bryn-Dafydd, the coal lying here again close on top of the sandstone. There is, therefore, no doubt that the Four-Foot Vein lies at a greatly higher level on the north-west than on the south-east side of the Llan Valley.

The difference in level, in view of the fact that the dip is uniformly north-westwards, cannot be accounted for by a roll,

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but must be due to a fault. On attempting to locate the fault precisely we are met with the difficulty that the ground is much obscured by drift and swamp, but there is sufficient evidence to show that it must run in a direction somewhat east of north. It must pass between the Kent Pit at Cadle and the Five-Foot workings of Carn-gôch. It was not reached in the Five-Foot workings from Mynydd-newydd, nor on the other side does it intersect the edge of the sandstone plateau along the drive to Penllergare. It must be to the west of some small riders which crop out near Glyn-siling (if, as seems likely, these are the riders of the Four-Foot seam), but it must lie to the east of a quarry in the sandstone 500 yards west of Cil-fŵnwr. Lastly, it must run to the east of Tredegar-fawr, for the Melin Llan Veins can be traced continuously up the sides of the Llan Valley to that farm. Piecing this evidence together, we may conclude that it passes somewhat west of Pont Cadle, under the Lake, giving rise to a strong issue of chalybeate water in the bank of the river 400 yards above the lake; that it runs thence to Tir-ffordd along a line where solid sandstone ground gives place suddenly to deep gravel, and that it passes east of Tredegar under the alluvial flats and drift-covered ground to the neighbourhood of Fforest-newydd. Further north, in the crop of the Graigola Vein, no sign is found of its existence.

NORTH STAFFORDSHIRE.

The resurvey of the North Staffordshire coalfield and surrounding ground has been continued during the past year by MESSRS. GIBSON, POCOCK, and WEDD, under the superintendence of MR. FOX STRANGWAYS. MR. GIBSON has commenced the survey of the Carboniferous, Triassic, and superficial deposits near Market Drayton; MESSRS. POCOCK and WEDD have been engaged in the survey of the same rocks round Macclesfield, Biddulph, and Congleton. A considerable time was taken up by MESSRS. GIBSON and WEDD in completing the collection of mining information relating to the Pottery coalfield. This has been a somewhat laborious task, owing to the number of collieries to be visited and to the complicated system of faulting and folding affecting the Coal-measures. In this work the Geological Survey has to thank the colliery managers, mining engineers, and surveyors for their courtesy in allowing access to plans, and for placing at our disposal their knowledge obtained in underground workings. The Map (Sheet 123, New Series) containing the major portion of the coalfield will be published during the year, and it is hoped that a Memoir, descriptive and explanatory of the map, together with a sheet of Vertical Sections, illustrating the character and thickness of the Coal-measures, will shortly follow the map.

Mr. Gibson.

The more important results obtained during the resurvey of the coalfield have been given in former Summaries. In that for 1899 it was stated that the subdivisions of the higher Coal-measures in North Staffordshire were found in the bore-hole at

Thurgarton, near Nottingham, underlying the Magnesian Limestone series. With the object of ascertaining the distribution of these deposits over the Midlands, MR. GIBSON visited and examined the typical sections of the higher Coal-measures in Denbighshire and South Staffordshire. In the sections visible on the banks of the Ceriog and Dee, between Chirk and Wynn-stay, he recognises the same sequence of red and grey rocks which succeed the productive Coal-measures in North Staffordshire. The "Etruria marls" are well shown in the banks of the Ceriog, between Chirk and Coed yr Allt. In Pentre-isaf ravine two bands of entomostracan limestone, containing *Carbonia*, occur near the base and middle of the marls. The lowest band, about 1 ft. 2 in. thick, is a light grey, fine-grained, earthy limestone, in which entomostraca and *Spirorbis* are sparsely distributed.* The higher band is a dark grey crystalline limestone containing entomostraca. The beds of green and greenish yellow grits, so characteristic of the Etruria marls in North Staffordshire and at Thurgarton, crop out on the banks of the Dee and Ceriog to the east of Chirk. It is noteworthy that the included fragments are larger and more angular than in North Staffordshire, and include fragments and chips of Silurian rocks derived from the neighbouring Denbighshire Hills. In Glyn Morlas, a tributary of the Ceriog, the purple mottled marls pass up into grey sandstones and shales containing, at Ifton Heath Colliery, four thin seams of coal. Similar sandstones and shales form the steep escarpment in Coed yr allt Wood, and are said by MR. DAVIES† to include nodules and bands of calcareous rock. At the junction of the red and grey series in Glyn Morlas a thin band of limestone is developed containing *Carbonia* and *Anthracomya calcifera*, the latter being a small fossil distinctive of the limestone at the base of the "Newcastle series."‡ This grey set of rocks graduates upwards into lavender-coloured sandstones and marls identical in character with the "Keele Series," succeeding the "Newcastle-under-Lyme series," of the Pottery coalfield.

The same upward succession of red marls with green rocks followed by grey sandstones and shales, with an entomostracan limestone at the base, and succeeded by lavender-coloured sandstones and marls, can be seen near Ruabon and Wrexham, where the lower marls are largely used, as in Staffordshire, in the manufacture of bricks and drain-pipes. Near Wrexham the upper red marls (Keele Series) make good terra cotta ware, but they have not yet been put to this use in Staffordshire, though they will possibly be tried near Silverdale. The stratigraphical succession in Denbighshire and North Staffordshire is thus so nearly identical that there seems no doubt that the same conditions were prevalent in both districts at the close of the Carboniferous

* See MR. D. C. DAVIES, *Quart. Journ. Geol. Soc.*, vol. xxxiii., p. 10. (1877.)

† *Op. cit.*

‡ *Summary of Progress*, 1899, p. 110.

Mr. Gibson. period. That these coalfields are connected underneath the Triassic deposits of the Cheshire plain is evident.

A closely similar succession can be made out on the northern flanks of the Clent Hills between St. Kenelms and Old Hill. Some years ago MR. GIBSON mapped portions of this ground in connection with the field-class at the University, Birmingham. During his leave of absence last Christmas he revisited the sections between Old Hill and St. Kenelms, and found the red marls at Old Hill, used in the manufacture of the famous South Staffordshire blue bricks, to be identical in lithological character with the Etruria and Ruabon marls, and to contain the characteristic bands of green and greenish yellow grits and breccias. The latter are frequently very coarse and angular, containing numerous fragments derived from the neighbouring Cambrian and pre-Cambrian rocks of the Lickey Hills.

It is a point of considerable interest, scientific and commercial, that in Denbighshire and South Staffordshire, where the Coal-measures are close to or abut against the pre-Carboniferous rocks, the green grits and breccias contain large angular fragments of these rocks, whereas at Thurgarton and in North Staffordshire the green grits are much finer, and contain only small rounded fragments of older rocks.

The Old Hill marls are succeeded by the Halesowen sandstone group, a series of grey sandstones and shales, with thin coal-seams. Thin bands and nodules of earthy limestone (peldon) are developed throughout the series, but do not appear to contain any organisms. Similar bands of "peldon" are recorded from many bore-holes and shaft-sections sunk through the red Triassic rocks to the Coal-measures outside the South Staffordshire coalfield. A bed of grey limestone at the junction of the Old Hill marls with the Halesowen group yielded, near Halesowen, a few entomostraca. The Halesowen group is succeeded by a thin series of red, grey and olive-coloured shales and sandstones, with a band of *Spirorbis*-limestone and a few thin coals.* These are apparently represented in North Staffordshire by the grey measures in the Trentham boring at a depth of between 551 feet and 575 feet. They are followed in South Staffordshire by the lavender-coloured sandstones and marls of Hunnington, which are indistinguishable in lithological characters, from the Keele sandstones and marls. With the exception, therefore, of the thin limestone with *Spirorbis* at the top of the Halesowen group, the succession in South Staffordshire is identical with that in North Staffordshire. The wonderful similarity, even in details, in the character of the higher Coal-measures throughout the Midlands, no doubt indicates that the same conditions prevailed towards the close of the Carboniferous period, over an area extending from Nottingham to Denbighshire, and from Lancashire to the Lickey and Clent Hills.

It remains to be ascertained whether the so-called "Upper

* PROF. LAPWORTH, Proc. Geol. Assoc., 1898, p. 366.

Coal-measures" of Coalbrookdale and the Forest of Wyre and Mr. Gibson. Malvern Hills correspond with the higher measures of the other Midland coalfields. In North Staffordshire there is no break in the stratigraphical series from the lowest workable seam (Winpenny) to the highest measures (Keele series), whereas in the Coalbrookdale and Malvern areas a very marked discordance is said to divide the Upper and Middle measures. MR. GIBSON has been led to believe that over a large part of the Midlands no great break occurs, but only local irregularities and overlap, and that when a borehole fails to prove the productive measures below the higher measures, it will probably be found that the former have been cut out entirely or in part by one of those powerful faults from which none of the Midland coalfields are free.

To the south-east of Market Drayton the same geologist has commenced the examination of the red rocks which have been considered to belong to the Permian system. They consist of irregularly-bedded red sandstones and red marls, admirably shown, as noted by PROF. HULL, in the long canal cutting between Tyrley Lock and Cheswardine. They are arranged in an anticline, surrounded on all sides by rocks of Triassic age. As they have yielded no fossils their age is doubtful. They bear considerable resemblance, however, to the higher portions of the Keele series as developed at Muckleston and Moddershall. In a coppice near Chipnall wood a shallow shaft is said to have passed through a coal lying in these red rocks.

Mention was made in the *Summary of Progress* for 1899, p. 108, of the occurrence of an ironstone overlying the Chalky Mine Ironstone of Clanway Colliery, Tunstall, and an analysis of the raw stone by MR. W. JACKSON, A.R.C.S., was then given. A further analysis has been made by DR. W. POLLARD of the calcined stone obtained from samples taken from several heaps of burnt ore, and is here inserted:—

Analysis of Calcined Iron Ore from Clanway Colliery, Tunstall. Seam overlying the "Chalky Mine."

SiO ₂	-	-	-	-	-	-	22.75	Total amount of iron 41.32 %
Al ₂ O ₃	-	-	-	-	-	-	10.96	
Fe ₂ O ₃	-	-	-	-	-	-	39.80	
FeO	-	-	-	-	-	-	17.31	
MnO	-	-	-	-	-	-	1.70	
CuO	-	-	-	-	-	-	Trace	
(MCo)O	-	-	-	-	-	-	.07	
BaO	-	-	-	-	-	-	.06	
CaO	-	-	-	-	-	-	2.98	
MgO	-	-	-	-	-	-	3.80	
P ₂ O ₅	-	-	-	-	-	-	.75	
S	-	-	-	-	-	-	.07	
H ₂ O	-	-	-	-	-	-	.12	
							100.37	

The amount of silica is higher than in any of the ores used in the district, and is only approached by the "Gubbin," with 14.53

Mr. Gibson. per cent. (J. HOMER, *Proc. Iron and Steel Inst.*, Sept. 7th, 1875, p. 562).

In the neighbourhood of Macclesfield MR. POCOCK, besides revising the subdivisions of Millstone-grit made by PROFESSOR GREEN, has traced the boundaries of similar sandstones in the Coal-measures as well as of the thin sandstones and quartzites in the grit and shale group below the Millstone-grit series. The number of these grit bands and the broken condition of the strata has somewhat impeded the progress of mapping. The following succession of strata has been ascertained, with approximate estimate of the thickness of the different members:—

1. Kerridge sandstone, 150 feet.
2. Measures with coal seams, 200 feet.
3. Millstone grits (four beds with shale partings), 550 feet.
4. Shales, } 400 or 500 feet.
5. Shale grit, }
6. Shales with earthy limestone and marine band, } base not seen.
7. Yoredale sandstones (Crowstones), }

In this table Nos. 6 and 7 correspond with the Yoredale division, as determined on the eastern side of the Pennine range. The sandstones and crowstones are hard splintery sandstones or quartzites, which rise from beneath the shales with a steep dip and form a prominent group of hills due south of Macclesfield, of which the highest, Croker Hill, is 1,200 ft. above the sea. Unlike the higher grits, these sandstones rarely present escarpment faces. They are thrown into a succession of sharp folds, on the north and south axis, and the declivities are generally dip-slopes. On the west the strata arch over and end abruptly against the New Red Sandstone which underlies the Cheshire plain. Their base is not seen, so that no measurement of their total thickness can be made. The thickest bed of crowstone may be nearly 100 feet thick, and is succeeded by two or three thin beds (15 or 20 feet) with separating shales. The shales with earthy limestone and marine bands have yielded *Goniatites* and *Aviculopecten papyraceus*, fossils common to measures lying above the 1st Grit. The series of grits in the Millstone-grit (3, 4, 5) is poorly represented. The long mural escarpments with broad valleys of softer strata which characterise the formation to the north and east have here given place to complicated ground, broken by cross valleys and faults into detached hillocks, where the only conspicuous shale features are those which separate the millstones from the Kerridge sandstone above and the shale-grit below. A close examination of the ground shows that the four divisions of the millstones are still present, but the shales which separate them are mere partings. Three miles to the north-east the grits open out into a succession of escarpments and dip-slopes, but they are there nearly 400 feet thicker than at Macclesfield.

The strata with coal-seams and the Kerridge sandstone are generally grouped with the Lower Coal-measures, but the grits do not differ essentially from those of the Millstone-grits, so that here, as elsewhere in England, the division between Coal-

measures and Millstone-grit is quite arbitrary. The seams of Mr. Gibson. coal are of small commercial value, and the few mines in which they were still worked at the time of the original geological survey of the district are now closed. The overlying sandstones form a conspicuous feature at the eastern edge of the Cheshire plain. They are largely quarried on Kerridge hill and at Bollington, and occasionally yield fine specimens of plants. Three distinct beds of sandstone, separated by shale partings, can be traced.

Further south, in the Biddulph and Congleton areas, MR. Mr. Wedd. WEDD finds a more complete series of the Lower Carboniferous rocks. The uppermost beds of the limestone which are brought up on a sharp fold in the quarries at Astbury, are associated with interbedded agglomerates and tuffs, as described by MESSRS. GIBSON and HIND.* They are succeeded by a series of calcareous shales and thin bands of dark impure limestone containing small goniatites, and a thin seam of impure coal lying 15 feet above the highest bed of tuff. Between these and the 3rd Grit a series of shales and grits forms the hill-slopes between the Astbury quarries and Congleton Edge. The four millstone grits of the Macclesfield area have apparently dwindled down to two, representing the first and third grits of the northern area. Along Mowcop a coal nearly four feet thick lies on the top of the third grit, and was formerly worked. A thin coal also overlies the first grit.

On the east side of the Biddulph Valley a coal corresponding in position to the Crabtree coal of Wetley Moor and Cheadle can easily be traced from Wickenstone to within a few yards of Woodhouse farm. The shale-roof contains numerous specimens of *Goniatites* and *Aviculopecten*, of the same species as occur above this coal in the Cheadle area. On the west side of the Biddulph Valley this coal seam has not been found, but its position is probably marked by a thin band of pebbly grit 250 feet above the first grit, which is similar to the grit forming the floor of the coal on the east side.

Owing to the steep dip of the strata and the covering of superficial deposits, little is seen of the measures above the first grit. It is certain, however, that they include no massive grit comparable to the Kerridge rock. The strata in the Biddulph Valley are thrown into a synclinal fold with a north and south axis, the position of which is accurately shown by a level course in the Newpool (Cockshead) coal at the Bradley Green Colliery.

The structure of the complicated ground between Harecastle and Astbury lime-works has not yet been fully made out. It is of considerable importance with reference to the occurrence of coal beneath the Triassic deposits to the west, and has received much local attention.

CULM OF DEVON AND CORNWALL.

A few additional particulars have been gleaned by MR. USSHER regarding the development and distribution of the Culm

* *Quart. Journ. Geol. Soc.*, vol. lv., 1899, p. 548-559.

Mr. Wedd. measures of Cornwall and Devon. In the region coloured Devonian on the published maps, he has found that some miles to the north of St. Germans, rocks resembling the Middle Culm appear in the form of fine, more or less, felspathic grits or sandstones, and dark shales or mudstones, with which they are occasionally interbanded. Lower Culm-measures form a small, in-lying, anticline at the north end of Amy Down. They also occur on Tor Down, Herod Down, Crendle Down, and Warrenleigh Plantation, Newton Ferrers House, and Dunnerdake. They consist of hard, shaly, and dark mudstones, with cherty bands and dark banded slaty shale, in which no definite succession could be detected. In the south part of Herod Down hard shaly beds, apparently in the upper part of the series, contain *Posidonomya* and *Goniatites spiralis*. In the adjacent road soft beds of the Brimley type occur. No limestones have been met with.

The Culm-measures around Chudleigh were surveyed on the old one-inch map in 1887, when no subdivision was contemplated beyond their separation from the Devonian Series. The district, north and west of Chudleigh, has been found to present the following succession in the Lower Culm-measures below the grits and shales of the Middle division:—

5. Hard and soft shales and hard, dense mudstones, with occasional bands of pale grey siliceous limestone and of chert. *Posidonomya*.
4. Cherty rocks and dark chert-beds intercalated with hard mudstones.
3. Local evidences of contemporaneous vulcanicity.
2. Very hard, dark, bedded mudstones, with thread-like, whitish banding at intervals.
1. Dark grey shales or slates.

The Lower Culm rocks have not yet been separated in the districts between Chudleigh and Kingsteignton, nor south of Bovey Tracey; but, in the area W. of Chudleigh, from Doddiscombsleigh to Bovey Tracey, their boundary with the overlying shales and grits is a well-marked stratigraphical line.

Advantage has been taken by MR. USSHER of the construction of the Teign Valley Extension Railway to examine the cuttings laid open along the line. Among Culm shales and grits of the Exeter type he observed in Perridge Tunnel an anticline which brings up dark mudstones containing *Goniatites*. This observation taken together with another made in 1887 near Tedburn St. Mary, where the uppermost beds of the Lower Culm were found with small *Goniatites*, demonstrates the constant repetition of the Culm rocks between Chudleigh and the Crediton valley, and proves that the upper beds of the Lower Culm are of a distinctly argillaceous character, while the overlying rocks are of the Exeter type.

GRANITE OF CORNWALL.

The various bosses of granite which in the south-west of Cornwall pierce the "killas" are not improbably like those of Devonshire, younger than the Culm-measures. But reference

may most conveniently be made to them in the present section **Mr. Wedd.** of this *Summary*. Those which extend from the Land's End to St. Ives and from Marazion towards Helston have been mapped by **MR. WILKINSON**. The large mass which lies to the west of Falmouth is now under examination by **MR. HILL**, who supplies some preliminary notes regarding it.

The mapping of the granite has so far been limited to the **Mr. Hill.** examination of a portion of the great Penryn mass. It is a grey acid, coarse-textured muscovite-granite consisting of orthoclase and plagioclase, abundant quartz, and both white and black mica, together with tourmaline in varying proportions. Porphyritic feldspars are commonly distributed, and include individuals of idiomorphic orthoclase exhibiting twinning of the Carlsbad type. Although not so coarsely crystalline as some of the other Cornish granites, which contain porphyritic feldspars of large size, like those of the Land's End type or of the mass near St. Austell, yet the Penryn rock presents a texture which, as compared with other British granites, is not only coarse as regards the matrix, but also in the size of its porphyritic feldspars which are often 2 or 3 inches in length. Although both muscovite and biotite are usually present, every variation may be observed in their relative abundance. In some sections muscovite may occur almost to the exclusion of the biotite, while in others the mica may be almost entirely biotite. Tourmaline occurs both as a constituent of the ground mass in which it generally takes the form of stumpy prisms, and as a later introduction coating the faces of joint planes in needle-shaped crystals which tend to dispose themselves in bunches. These needles sometimes attain a length of 2 or 3 inches. Tourmaline seems to be a conspicuous mineral in the more acid portions of the granite which vein the normal type. In some veins of coarse, acid granite tourmaline occurs to the exclusion of biotite, and some of the individuals have been noticed under these conditions as large as half an inch. Where such coarse acid veins have been observed to contain tourmaline as well as massive schorl, contiguous veins which are finer in texture are found to be rich in biotite, while tourmaline is then entirely absent. In the coarse veins containing tourmaline the mica that occurs is muscovite. Other instances have been observed where the only mica contained in the coarse acid veins is a white mica.

In that part of the Penryn granite which has yet been mapped no perceptible change of texture has been noticed at its outer edges. It should be mentioned, however, that sections showing actual junctions of this rock with the slate are rare, yet if the mass is looked at as a whole, a distinct difference of texture may be detected in it between the marginal parts which, broadly speaking, are finer grained than the interior, and are found to be somewhat heavier than the coarser grained material.

The comparative uniformity in the direction of the major joints in the granite over the whole Cornish area was long ago pointed out by **DE LA BECHE**. In the Penryn district, one set of vertical joints, having a prevalent direction of N. 10 deg. W., is

Mr. Hill.

crossed by another vertical set at right angles. These two systems, in conjunction with a third set more or less horizontal, divide the whole rock into a set of roughly prismatic segments. The great regularity of these joint planes has been an important factor in the rapid development of the granite industry of Cornwall, as compared with other localities in Britain. The joints have received local names. Those which trend N. 10 deg. W. are known as *cleaving way-joints*, those at right angles are the *tough way-joints*, while the horizontal joints are known as *floors* or *quartering way-joints*. The grain of the granite has been found to correspond with the position of the joints, hence their names.

The rock cleaves most readily along planes parallel to the floors or horizontal joints. The next easiest cleaving plane is that parallel to the cleaving way-joints (N. 10 deg. W.), while the rock cleaves most irregularly parallel to the tough-way joints. This rule is understood to hold good over the whole granite area. An examination of numerous sections in which all three types of jointing are visible appears to show a distinct tendency to orientation along planes parallel to the horizontal floors and to the cleaving-way joints, though no absolute regularity in this respect has been observed. While in many instances these joints trend away from the normal direction; it is unusual to find more than one joint deflected in the same exposure. The horizontal joints, although they often undulate, are the most regular of all. The cleaving planes of the rock are not always strictly parallel to the joints, yet, on the whole, the marked parallellism between the joints and the directions along which the rock most readily cleaves is unmistakable. From the evidence of a large number of sections there is reason to conclude that not only is there a close connection between the major joints and the grain of the rock, but that this grain is dependent on the internal mineral arrangement of the rock, and that all three phenomena are closely related. The uniformity in these structural features appears to be diffused over the whole granite mass, and may perhaps be found to be common to the whole of the granites of the West of England. The internal crystalline arrangement appears to consist first in a tendency for the mica to lie with its basal planes horizontal; secondly, in a disposition of the felspars both as constituents of the matrix and as porphyritic individuals, with their flat sides in a similar position; and thirdly, in the orientation of the felspars with their long axes parallel to the cleaving-way joints. The first and second of these structures probably explain the proneness to cleave parallel to the horizontal joints, while the third seems to show why the rock tends to cleave in planes parallel to the cleaving-way joints. The rock, however, presents no structures so defined as those of foliated rocks. It does not differ to any marked degree in outward appearance from ordinary granite. Yet it has evidently undergone a rude and initial stage of foliation, whereby its component minerals have been forced to rearrange themselves in a definite direction so as to acquire a cleavage.

The tough-way joints, or those which correspond roughly to a **Mr. Hill** direction E. 10 deg. N., may sometimes be faults, instances being common where the horizontal floors have been thrown by them as much as 2 feet, or where the joints display slickensided surfaces indicative of relative displacement of the walls. Further, the finer-grained granite veins tend to take a course parallel to these same joints, while the elvan dykes undoubtedly follow the same parallellism.

The horizontal joints or floors form one of the most characteristic features as seen in the field. **DE LA BECHE** considered them as original structures and not as produced at a comparatively late period by the decomposition of the outer crust. The fact that these horizontal joints have been faulted by the joints bearing E. 10 deg. N. proves them to be at least older than these tough-way lines of division. Later joints, however, occur which cannot always be distinguished from the true "floors" into which they appear to blend. The intervals between these horizontal joints or floors increase with depth from the surface. In one of the quarries the joints are 60 feet apart, while in another they are so favourably disposed that blocks of stone can be produced 120 feet long, 28 feet wide, and 30 feet deep.

The elvans display considerable irregularity in their jointing. One of these dykes, intruded along the "tough-way" of the granite, has a common "quartering-way" joint with that mass, while one of its dominant joints corresponds with the "cleaving-way" joints of the granite.

Although the junction of the granite with the slates can be rarely seen, the contact metamorphism of the latter may be sufficiently studied. As stated in former Reports, it presents an aureole of "knotted" slate, the innermost portions of which are crowded with minute scales of muscovite and biotite, while at the actual junction andalusite is abundant. The phenomena thus differ considerably from those displayed by the Land's End granite, near to which the sedimentary rocks are indurated and change into hornfels to such an extent that it is often difficult to distinguish these rocks from the greenstones.

As the survey of Cornwall has so recently been extended to the mining districts, the examination of the lodes has only been begun. The districts of Camborne and Redruth are now the principal seats of the mining industry, which is more or less scattered over the country. Notwithstanding the length of time since the Geological Survey maps of this district were completed and published, the principal mining operations are still carried on in the old lodes which are shown on the original maps. Tin is being extracted at present from a group of mines in the Camborne district at depths varying from 200 to 450 fathoms. The tin lode known in the district as the Great Flat lode has, however, been discovered since the first survey. It is extensively mined for tin, the workings descending to a depth of 300 fathoms. Besides these more important tin-producing mines, minor operations are conducted nearer the surface on lodes down to a depth of about 20 fathoms.

Mr. Hill.

The tin-stream-washing is almost at an end in the county, but operations of this kind are still carried on at Perran Porth and at Pen Pons near Camborne, while the advanced price of tin has led to the working of the old mining burrows with profit in various portions of the county. While tin forms the principal mineral at present raised in the county, copper is also worked, together with other metals, including arsenic, wolfram, and uranium.

Triassic.

LEICESTERSHIRE.

Mr. Fox-
Strangways.

The revision of the geological maps of Leicestershire and adjoining counties has led to a more precise delineation of the boundary-lines of the Triassic formations of that district. Thus, along the northern side of the Wreak Valley, between Melton and Loughborough, the Keuper Marl and Rhaetic group have been separated by MR. FOX STRANGWAYS. The Rhaetic outcrop has been traced northwards from Barrow, and the dark paper-shales are well exposed at Barrow Hill resting on the tea-green marls, with a thin bone-bed between them. Thence the outcrop may be followed through the village of Walton until it is lost under boulder-clay. Again, along the eastern side of the Soar Valley, where two well-marked outliers of Rhaetic and Liassic strata rise to the south and west of Gotham, the Keuper Marls contain an important bed of gypsum, which is extensively worked near the village, and has been traced for several miles. The outcrop of the Rhaetic beds is well shown along the steep sides of these outliers, but the bone-bed has not yet been detected here.

STAFFORDSHIRE, SHROPSHIRE, AND CHESHIRE.

Mr. Barrow.

In the Cheadle district further progress was made last spring by MR. BARROW, who mapped an additional tract of Bunter Sandstone and Keuper Marls. The most interesting part of his work consisted in the detection of some indications of discordance, possibly due to contemporaneous erosion in the Triassic series, and accompanied by traces of slipping along the sides of pre-Triassic valleys.

Mr. Gibson.

The Bunter group has been found by MR. GIBSON to be well developed around Market Drayton, where it is exposed in many natural sections. Possibly, however, only one of the three subdivisions of the group is here represented. Bands of false-bedded, laminated, non-pebbly, mottled red sandstones, indistinguishable from those usually classed as "Lower mottled," are developed at several horizons throughout the pebbly subdivision. One of these bands, occurring high up in the middle subdivision, has been mapped as Lower Mottled Sandstone on the published one-inch map. Near Tern Mill the non-pebbly sandstone can be seen resting on the coarse conglomeratic sandstones which rise to the south of Market Drayton. Near Tyrley Lock the lower subdivision may

be represented, but it passes upwards imperceptibly into the middle subdivision. In North Staffordshire the lower portion of the Bunter group may be said to consist of slightly pebbly sandstones, conglomerates, and shingle beds, with lenticular bands of non-pebbly sandstone, developed at the base and at higher horizons, but more frequently near the summit, when it constitutes the upper mottled subdivision. The coarseness of the sandstones and the frequency of the shingle-beds rapidly increase from west to east, till at Cocknage, on the south-eastern margin of the coalfield, the Bunter is represented by strong conglomeratic sandstones and numerous bands of coarse shingle, thus approaching to the Leicestershire type, which consists of shingle beds enclosing lenticles of sandstone.

In the Macclesfield district, which is undergoing revision by Mr. Pocock, the New Red Sandstone is almost entirely buried under thick drift. A ridge of it runs in a south-easterly direction from Alderley Edge, and comes to the surface near Radcliffe Wood. Yellow sandstones with a few small pebbles abut against the steep slope of Yoredale sandstones. No great thickness of sandstones is seen, and they pass up conformably into red marls, which overlap the sandstones till they come into contact with the Carboniferous rocks. The Trias rocks do not show any sign of disturbance along the line of junction, their boundary-line pointing rather to their having been deposited against a steep face of Carboniferous rocks.

In the Congleton district surveyed by Mr. Wedd the junction of the newer and older formations is undoubtedly a fault. Thus in the stream flowing west from Congleton Edge through Limekiln Wood the Trias can be seen faulted against Carboniferous strata. A faulted junction is also visible half-a-mile west of Mowcop close to Grotto Wood. In the Lawton Pit, west of Harecastle, the red rock is proved in a stone drift, and the junction is described as a fault. The workings of the Bunkers Hill Colliery also prove the junction between the Trias and Coal Measures to be a fault of unknown amount with a downthrow to the west. The western margin of the Pottery Coalfield along its entire length from Madeley to Talke is bounded by a large fault which can be proved to affect both the Trias and Coal Measures at Bar Hill, Mucklestone, and Madeley Manor.

In the small strip of Trias, on the western flanks of Mowcop and Congleton Edge, the Bunter division is seen at intervals. East of Mowcop station the Keuper division is faulted against Bunter, and soon passes under red marls which gradually overlap the Bunter formation.

ISLE OF ARRAN.

The important discovery of Rhaetic fossils in Arran, announced in the *Summary of Progress* for 1899, was followed up last year by a further search, which was rewarded by the discovery of a large assemblage of fossils of Rhaetic, Liassic, and Cretaceous ages. The strata containing these fossils are not in place, but occur as large masses within an old volcanic vent, into which

Mr. Wedd

they must have fallen from above. The circumstances of their occurrence will therefore be more appropriately described in the pages of the present volume, which treat of the Tertiary volcanic rocks of Scotland. It may suffice to state here that the discovery of masses of abundantly fossiliferous Rhaetic shale in Arran affords the strongest proof that the newer red sandstones of the southern half of the island are really Triassic. The age of these strata has long been in dispute. They have been regarded as Old Red Sandstone, Carboniferous, and New Red Sandstone. It is interesting to note that the final determination established by the fossils confirms the original conclusion of SEDGWICK and MURCHISON that the rocks belong to the "New Red Sandstone."

The discovery of Rhaetic fossils in Arran has led to the re-examination of some specimens collected by MR. H. B. WOODWARD in 1892 in the passage-beds between Trias and Lias at Eyre Burn, on the south of Raasay. The fossils recognised by MR. E. T. NEWTON are *Modiola*, *Pecten*, and *Pleuromya*, cf. *crowcombeia*, not sufficiently definite in themselves to prove their Rhaetic age, but interesting to record, as similar and better-preserved examples have since been found in Skye in the passage-beds between Trias and Lias.

Jurassic.

CAMBRIDGESHIRE AND HUNTINGDONSHIRE.

During the past year it was found desirable to trace some new lines over a considerable area of the eastern half of Sheet 187 (new series) in the counties of Cambridge and Huntingdon. MR. WEDD, who was detailed for this duty, separated the Ampthill Clay, with the Elsworth and St. Ives Rock at its base, from the Kimeridge Clay above and the Oxford Clay below. He has traced the outcrop of the Elsworth and St. Ives band more or less continuously for some twelve or fifteen miles from the neighbourhood of Croxton in the south, through Yelling, Papworth Everard, Elsworth, Hilton and Fen Drayton to the Ouse Valley in the north; and again on the north side of the Ouse Valley, from Houghton Hall in the west, through St. Ives, Needingworth, and Holywell. It appears that all the ground to the east of this outcrop for some distance is Ampthill Clay, while that lying to the west is Oxford Clay. A layer of phosphatic nodules has, where seen, been taken as the upper limit of the Ampthill Clay, as suggested by the late T. ROBERTS.

ISLE OF ARRAN

In the same Tertiary volcanic vent to which reference has been made in the Triassic section of this *Summary* large blocks of dark shale are likewise included, from which a number of characteristic Lower Lias fossils have been obtained. An account of these fossils will be given in the Paleontological sub-division. Their discovery is of the highest interest, as they clearly prove that the Lower Lias extended from the north of Ireland at least as far as the present basin of the Clyde.

ISLE OF SKYE.

As it was necessary to complete the mapping of the Jurassic Mr. Wedd. formations of Skye with a view to the publication of one of the Sheets of the map, and as MR. WOODWARD's administrative duties prevented him from continuing his former survey there, MR. WEDD took up the work where MR. WOODWARD had left it. Stationing himself on the west side of the Jurassic district, he found immediately below the Tertiary basalts on the west side of Loch Slapin a series of dark, sandy, micaceous shales and shaly sandstones, with many hollow casts of Belemnites, and Ammonites, and *Pecten fibrosus*. The presence of Ammonites, which appear to be *A. cordatus*, shows these beds probably to belong to a horizon not lower than Upper Oxfordian. They are underlain by a well-marked horizon of blue sandy limestones and calcareous grits, with thin shales and a bed of small oysters (*Ostrea hebridica* ?), apparently of estuarine origin, and belonging to the Great Oolite or Loch Staffin series. These pass down into shales full of crushed lamellibranchs (*Cyrena* ?), overlying a white saccharoid sandstone, 30—40 feet thick, apparently of freshwater or estuarine origin (Inferior Oolite ?). This passes down into marine shales with indeterminable ammonites, and below these shales comes a thick series of white sandstones and grey calcareous grits, with marine fossils (*Terebratula* sp., *Rhynchonella tetrahedra* ?), forming the cliffs on the west side of Loch Slapin.

When traced northwards to the head of Loch Slapin, the upper part of the Jurassic formations is seen to be much metamorphosed in the neighbourhood of the Tertiary granite of the Red Hills. The oyster-bed can be recognised as a grey mottled marble, and the black shales are seen for some distance to be baked into a substance resembling white porcelain. On the east side of Loch Slapin, at its head, hardened sandy shales are faulted in against the Durness limestone. These have all the appearance of Pabba shales, but no determinable fossils have yet been found in them. On the east side of Loch Slapin, further south, the *Bucklandi*-zone of the Lower Lias is seen to overlap the Durness limestone. In Strath the subdivisions of the Lower Lias, suggested by MR. WOODWARD for the Broadford district, hold good for some distance westward. The base of the Lias is here marked by a series of whitish pebbly grits; a few feet should apparently be assigned to the Rhaetic group, but there is no definite plane of demarcation from the Trias. Lower, pebbly Triassic sandstones, with a bed of red and green marls near the top, lie unconformably on Torridon Sandstone or on Durness Limestone; but the Trias and the lowest strata of the Lias disappear in turn westwards owing to the overlap of higher stages of Lias.

Cretaceous.

WILTSHIRE AND DORSET.

Mr. Clement
Reid.

The detailed mapping of the Vale of Wardour by MR. CLEMENT REID has clearly proved the conformity of the Wealden to the Purbeck strata. It has also shown that a nearly steady eastward dip affects these rocks, and that they were denuded and truncated before the so-called Lower Greensand was deposited on their upturned edges. The only representative of the Lower Greensand that can be found here seems to be some 20 or 30 feet of coarse glauconitic sands, more or less loamy, and containing nodules of cherty sandstone. These sands appear to lie perfectly conformably to the Gault above, though separated from it by a bed of pebbles. At their base, there is usually a similar bed of pebbles, which rests unconformably on various strata of older date. No clear evidence for any other Lower Greensand has yet been found in the Vale, and as corresponding strata a few miles to the south-west have been shown by MR. R. B. NEWTON to yield the fauna of the zone of *Ammonites mammillatus*, it seems probable that the deposits in the Vale of Wardour also represent this highest division alone of the Lower Greensand. Sections of these strata are here rare, and the only fossils that could be found were sponge-spicules and moulds of *Pecten orbicularis* and *P. 5-costatus*, all contained in loose blocks of cherty sandstone, which are so like certain parts of the Upper Greensand that one cannot be perfectly sure that surface specimens are of older date.

DR. A. W. ROWE'S work on the variation of the Micrasters has proved useful in this district, which yields sub-zonal forms like those obtained on the coast. By means of these fossils it is now possible accurately to trace the lower boundary of the Upper Chalk in regions where the Chalk Rock cannot be found, or in which there occur two or three beds of Chalk Rock.

In view of the growing urgency of the question of water-supply throughout the South of England, it is most important to ascertain accurately the limits and thicknesses of the different divisions of the Chalk, which is one of our principal water-bearing formations. Slight undulations, such as were overlooked in this homogeneous rock before the divisions were mapped, are now known to form underground water-partings, by raising the hidden impervious beds below; these shed the water in opposite directions, and isolate catchment areas formerly thought to be continuous. A thorough knowledge of the limits of these catchment areas is a necessary preliminary to the allotment of the different basins to different towns or districts. It should be borne in mind that where the surface rocks are porous the numbers and limits of these basins do not correspond at all closely with the supposed "catchment areas" or river basins mapped out in the ordinary way by surface contours.

Mr. Dixon.

In the Upper Cretaceous area around Maiden Newton (Sheet 327), MR. DIXON notes the sharp lithological and palæontological

division between the Lower Chalk and the Upper Greensand Mr. Tison, the lowest part of the Chalk being glauconitic, sandy marl, usually crowded with phosphatic fossils, especially Cephalopoda of Lower Chalk age; whereas the uppermost part of the Greensand is a hard, coarse, calcareous and glauconitic grit, containing *Pecten asper* and other Upper Greensand fossils.

SUSSEX.

The area surveyed in this county last year by MR. LAMPLUGH, Mr. Lamp-measuring 41½ square miles, completes the survey of Sheet 317 lugh. of the New Series One-inch Map, and as the results obtained will be published shortly in the Memoir on that Sheet, only a brief outline of them need be given here. The ground lies mainly to the east of the Arun River, and consists, in its southern portion, of the Upper Greensand, Gault, and the various subdivisions of the Lower Greensand described in the *Summary of Progress* for 1899, and in its northern portion, of the Weald Clay. It includes the western part of the "Greenhurst anticline," where a narrow tongue of Weald Clay is brought up by a sharp fold in the Lower Greensand.

The Lower Greensand and overlying divisions showed little alteration from the characters already described, and will not be further discussed.

The Weald Clay was examined over a triangular tract with a base four miles in length at the eastern edge of the ground, and its apex in the west, near Petworth. Where broadest, probably about half the total thickness of the Weald Clay was represented in this tract. It included a considerable portion of the area mapped and described with remarkable accuracy by MR. P. I. MARTIN so long ago as 1828. The bands of sand and of Sussex Marble by which this observer divided the Weald Clay into belts were traced out wherever possible, and although found not to be quite so regular and continuous as he supposed, their general succession was in full agreement with his descriptions. The details of these bands and their local distribution will be given in the forthcoming Memoir. The occurrence of the sandy horizons has much economic consequence, as they are the main source of water supply in the Weald Clay tract; and moreover by their admixture with the clay where near the surface, they change the character of the soil from an untractable clay-land, which under present conditions will not pay for cultivation, to a more readily arable loam. Beds of this character underlie the major portion of the arable land in this part of the Weald, while the unmodified clay-belts lie for the most part under grass or woodland. The beds of sand, though thus materially affecting the land, are usually too thin or too much interstratified with clay to make a really "light" soil, especially as the clays tend everywhere to "creep" and become mixed with the sands along the outcrop.

The water-supply from wells in the sands is often tainted with mineral matter in solution, and is usually only sufficient in

Mr. Lamp-
lugh.

quantity for household supply, but is important in a district where no other safe source is available.

The sands and limestone bands generally form gentle features along their outcrop, but owing to their slight thickness and the above-mentioned "creep" of the clays on the slopes, it is rare that the beds are visible in these features, the exposures being usually found in gutters and ponds, on the lower part of the long gentle dip-slope under a thickness of 2 or 3 feet or more of clay.

There is every gradation between sand and clay, the silty intermediate beds being often finely laminated. From the spoil-heap of a new well, sunk to a depth of 40 feet in beds of this description at a cottage opposite to Marringdean Farm, south of Billingham Station, a few well-preserved plant-remains were obtained. These were submitted to MR. A. C. SEWARD, F.R.S., who kindly undertook their determination and recognised the following species:—

Weichselia Mantelli, Brongn.

Onychiopsis Mantelli, Brongn.

Brachyphyllum sp.

The flora of the Weald Clay, as distinguished from that of the Hastings Beds, is imperfectly known, so that the occurrence of these plants is of some interest, though they belong to widely distributed Wealden forms. The horizon at which they occur is about midway in the Weald Clay of this part of Sussex.

Atherfield Clay.—Comment was made in last *Summary of Progress* on the difficulty in obtaining definite evidence respecting the Atherfield Clay in Sussex. During the present year, however, indications of the presence of this clay were found at several points, the clearest being in a road-cutting near Warminghurst, at the eastern margin of the ground surveyed, where the sandy Hythe Beds are seen to pass down into greyish brown and chocolate-brown clay, with small phosphatic concretions containing casts of marine shells. This clay, which was apparently not more and might be less than 20 feet thick, rested directly and sharply upon dark blue shaly clay, evidently the topmost bed of the Weald Clay. This confirmation of the correctness of the old map in regard to the presence of the Atherfield Clay in Sussex is the more satisfactory since the new railway-cutting at Redhill, on the opposite side of the Weald, showed the unexpected absence of the division.

SURREY.

In regard to the Redhill section, just referred to, it may be stated that during last summer the railway-cutting between Redhill and Earlswood, on the London, Brighton, and South Coast Railway, was widened, and that as this cutting exposes the junction of the Lower Greensand with the Weald Clay, which is so rarely visible, the opportunity was taken for studying the section during the progress of the work. The results are of considerable interest, especially in showing the unexpected

absence of the Atherfield Clay, this deposit having hitherto Mr. Lamp- been supposed to be continuous all around the Weald, as indi- lugh- cated on the published geological map. The section exposed on the eastern side of the cutting, and now again concealed, was as follows:—

Hythe Beds :—

ft. in.

Ashy grey and yellow loamy sand with large ferruginous concretions towards base; containing many casts of shells in the lower part and in the concretions, including <i>Exogyra</i> , <i>Terebratula</i> , <i>Lucina</i> , <i>Pholodomya</i> , <i>Pecten</i> , and <i>Pinna</i> , seen about - - - - -	12	0
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resting sharply on—

Weald Clay :—

Dark shaly blue clay much broken up, and partly mixed with loam which has apparently filled borings in the clay - - - - -	0	4
Dark blue clay more or less interlaminated and interbedded with greenish-grey and whitish silt, much crumpled and broken in places in the upper part - - - - -	4	9
Brown indurated clay with laminæ of pale silt; containing many Cyprids, and fragments of fishes - - - - -	0	3
Laminated blue and black clay and pale silt; the thicker silty beds much broken - - - - -	2	0
Brown indurated clay, with shells at base, including <i>Cyrena</i> , <i>Vicarya</i> , and <i>Ostrea</i> - - - - -	0	2
Laminated blue clay and pale silt, with a band of small pyritous nodules - - - - -	2	7
Dark clay streaked with white silt, with a 2 in. brown band crowded with cyprids and fish-remains - - - - -	4	6
Clay-ironstone band, with cyprids, fish-scales, etc. (much broken towards outcrop) - - - - -	0	3
Dark shaly clay with greenish-grey silt in laminæ and in thin beds - - - - -	9	6
Clay-ironstone band full of <i>Cyrena</i> , cyprids, and fish-remains, also containing <i>Vicarya</i> , <i>Cardita</i> ? - - - - -	0	3
Dark shaly blue clay containing shells as above, also a small oyster - - - - -	1	0
Blue clay streaked and interbedded with pale silt - - - - -	7	9
Dark clay streaked with silt, containing shells (<i>Unio</i> ?) at base - - - - -	2	8
Clay ironstone band with cyprids, fish-remains, and shells— <i>Cyrena</i> and <i>Paludina</i> - - - - -	0	2
Dark blue clay streaked with pale silt, lower beds not seen - - - - -	2	6

Thickness of Weald Clay examined - - - 38 8

There was no sign of weathering, erosion, or unconformability at the top of the Weald Clay in this section, except that it appeared to have been penetrated for a few inches by the burrows of marine organisms. The superficial crumpling and breaking up of the bedding which prevailed for some feet below the junction was probably due to slight differential creep or drag between the clay and the overlying mass of sands during consolidation; it is a feature commonly to be observed under like circumstances in the softer Secondary formations. The Weald Clay of this section bore a remarkably close resemblance lithologically to the Wealden shales occupying a similar position at the top of the Wealden series in the Isle of Wight, and the presence of brackish water

Mr. Lamplugh.

forms among the fossils in both places establishes the correlation. As similar forms have been recorded from the top of the clay at two other localities in the Weald,* one lying far to the eastward, and the other to the westward of Redhill, it is probable that the incoming of marine conditions is foreshadowed throughout the whole area by fossiliferous bands of this character, although the junction with the base of the overlying marine series appears to be everywhere sharply drawn.

The marine fossils mentioned in the Weald Memoir (p. 113) as having been obtained from the Atherfield Clay in a railway-cutting near Redhill, about one-third of a mile to the eastward of that above-described, appear, on reference to the original account given by FITTON, to have been collected from concretions at the base of the Hythe Beds similar to those found in the recent section, and cannot therefore be taken as proof of the presence of the Atherfield Clay at that point.

ISLE OF WIGHT.

The Lower Cretaceous coast-sections in the Isle of Wight were examined by MR. LAMPLUGH during a short visit at the end of September for the purpose of comparing them with the rocks of the same age recently surveyed in Sussex, and of obtaining information for the General Memoir on the Lower Cretaceous formations of England. The material collected during this visit has not yet been through the hands of the palæontologists, so that the wider results of the investigation cannot at present be given, but opportunity is taken to place on record a few facts which add to our knowledge of the subject.

1. Fossils were found in the Carstone, in the form of casts in small phosphatised concretions, wherever this division was accessible, viz., at Redcliff, near Sandown; at Bonchurch Cliff; on the slopes south-east of Blackgang (the best collecting ground); and at Compton Bay. The majority of these fossils are probably species already included in the scanty published list from this division, but some are new to it. They include some imperfect *Ammonites*, perhaps not determinable but certainly not *Ammonites mammillatus*.

2. The Sand-rock series in the slopes south-east of Blackgang yielded casts of marine bivalves and plant-remains in a band of ferruginous concretions 10 feet below the base of the Carstone. Shells do not appear to have been previously recorded from this division.

3. In the Ferruginous Sands of Little Stairs Point, south of Sandown, there occurred a transported slab of Kimeridge shale, measuring 8 in. $\times$ 6 in. $\times$ $\frac{1}{2}$ in., much bored by pholades, which is of interest in showing that erosion of the Upper Jurassic rocks was in progress at no great distance during the deposition of these sands. The slab was also interesting in that it contained, along with other fossils, numerous specimens of a

* See Survey Memoir, "Geology of the Weald," pp. 98-99.

small delicately-sculptured organism at present undetermined, **Mr. Lamp-** but possibly a crustacean, which was only previously known to **ugh.** us from a low horizon in the Kimeridge clay in one of the recent deep borings in Kent.

4. On the beach and at the foot of the cliff a little to the southward of Shanklin Chine, an irregular pebble-bed, containing pebbles up to 4 inches or more in diameter, was exposed in the Ferruginous Sands, which does not appear to have been previously observed. The larger pebbles, mostly sub-angular or partly rounded, were composed of a pale green-stained sandy rock, partly made up of fragments of shells, which may represent a decomposed sandy limestone or chert, possibly derived from the Purbecks; other pebbles were of brown sandstone, and many of the smaller ones, well-rounded, up to an inch and a-half in diameter, were of white vein-quartz. The pebbly band was associated with fine clay and silt containing large pieces of fossil wood. This is the coarsest pebble-bed known in the series in the Island, and as it occurs in the middle of a subdivision, with no sign of erosion or unconformity in the underlying bed, it shows how little confidence can be placed in the mere presence of such a bed, as evidence for a break in the sequence.

5. As regards the general correlation of the Lower Greensand of the Wealden district with that of the Isle of Wight, it is clear that the divisions adopted in the respective areas, on lithological consideration, have not their boundaries in common, and, therefore, cannot be directly compared. Neither are the fossils sufficiently numerous or distinctive to give much hope for palæontological classification, since the bivalves which constitute the principal element in the fauna are mostly of wide range in time, though apparently rather narrowly localised in their mode of occurrence, or, at any rate, in their preservation. The Trigonias seem to offer the most likely prospect of service in this direction, and might be worth further study.

The following seems on the whole to be the most probable relationship of the Lower Greensand divisions of the two districts:—

Isle of Wight.

West Sussex.

Gault.	Gault.
Carstone.	Folkestone Beds.
Sand-rock Series.	Sandgate Beds.
Ferruginous Sands.	Hythe Beds.
Atherfield Clay.	Atherfield Clay.
Wealden Shales.	Upper part of Weald Clay.

OXFORDSHIRE.

Mr. J. H.
Blake.

The Lower Greensand has been resurveyed by MR. J. H. BLAKE at Nuneham Park and around Marsh Baldon. To the east of the latter place he found in more or less cherty sandstone beds some marine fossils, of which the following have been identified by MR. E. T. NEWTON:—

Ammonites sp. Three fragments, one of which may be *A. nutfieldensis*, but is too imperfect for identification.

Pecten orbicularis, Sow. Two specimens.

Cardium, near to *peregrinorsum*, d'Orb.

Astarte? Small inflated shell with few concentric ribs.

Ostrea sp. Five specimens, may be several species.

"Although the specimens can scarcely be taken to prove the strata to be of Lower Greensand age, yet their general facies points to that conclusion."—E. T. N.

The only fossils previously recorded from the sands, presumably Lower Greensand, in this district were *Ammonites Deshayesi* and *Terebratula sella*, which were found in the road-cutting at Toot Baldon by PROF. (SIR A.) RAMSAY, MR. ETHERIDGE and MR. HULL, during a tour of inspection about the year 1860 or 1861. The sands in many parts of Nuneham Park are of a coarse quartzose character. A recent excavation west of the Lodge in the south-eastern corner of the Park, showed 4 feet of chocolate-coloured coarse quartzose loose sand overlying 4 feet of ferruginous and indurated coarse sand, thinly bedded, locally known as "roach," and used for metalling paths.

Modifications have been made in the boundaries of the Gault in the neighbourhood of Stadhampton, Chislehampton, and Drayton. The hill to the north-west of Chislehampton has been proved by a boring 60 feet in depth, made this year near the top of the sloping ground opposite Church Farm, to consist of bluish-grey clay, blackish in places. It is apparently Gault overlying Kimeridge Clay; whereas, it is shown as Lower Greensand on the Geological Survey Map, Sheet 13 (Old Series).

At Clare Brick-works, two miles N.E. of Chalgrove, a new section 3 feet in depth showed light blue-grey clay, containing a little "race," a few ferruginous concretions, and some small phosphatic nodules. MR. BLAKE obtained a portion of *Ammonites* (*Schlaenbachia*) *rostratus*, Sow., identified by MR. E. T. NEWTON.

ISLE OF ARRAN.

Mr. Peach
and Mr.
Gunn

The same great volcanic vent, which has been already referred to as proving the former extension of Rhætic and Liassic strata into the basin of the Firth of Clyde, has likewise yielded large included masses of white limestone and chert, from which numerous unmistakeable Chalk fossils have been obtained. These are further referred to at pp. 111 and 112. They are alluded to here for their importance as proofs that the Upper

Cretaceous rocks, which now end off on the north coast of Antrim, once stretched eastwards at least as far as Arran. Indeed there seems no reason why these later Mesozoic formations should not have spread far over the south of Scotland. The denudation of that region since Tertiary time, as proved by the numerous wide and deep valleys cut across the younger dykes, has been so enormous as to have removed hundreds of feet of material from the surface of the country.

Mr. Peach
and Mr.
Gunn.

Tertiary.

HAMPSHIRE BASIN.

The past season having seen the completion of the re-mapping of the Hampshire Basin, this may be a convenient point at which to summarise the leading results obtained by the new Survey of the Tertiary deposits of this region. Without going into minor details, we may state that the main points brought out are: The striking tendency of the successive divisions to become gravelly and to overlap lower ones towards the west and south-west, as though high land lay in that direction. This is well illustrated by MR. REID's observations of coarse gravel with much Palæozoic material at the base of the Reading Beds towards their south-west limit, where also they have cut deeply into the Chalk. In the Bagshot Sands also there is a general increased coarseness of the material towards the west; and ultimately where the Sands overlap the Lower Eocene and rest on the Chalk they change into coarse gravels, like those of the Reading Beds, but containing also fragments of Jurassic rocks, and of greywether sandstone. A slighter overlap seems to occur at the base of the Bracklesham Beds. Finally, during the past season, MR. DIXON has shown that the pebbly base of the London Clay also cuts through the Reading Beds, and rests upon Chalk.

Mr. Clement
Reid.

The Oligocene strata are preserved over so limited an area that no overlap of them has been proved. There occurs however, a striking change towards the south-west, in which direction tufaceous limestones—entirely absent on the mainland, and rare and thin to the north and north-east, become conspicuous at several stages in the Headon Series of the Isle of Wight, while land-shells and angular stones are more abundant than elsewhere. It looks as if these strata within two or three miles might have been found to abut against older deposits, were it not that all direct evidence has been destroyed by denudation. Another point brought out by the 6-inch mapping is the greater sharpness and depth of the east and west folds. For instance, an increased thickness and a large additional area of Hamstead Beds has been proved in the Isle of Wight syncline, the Portsdown anticline has been shown to extend much further west than was thought, and the Chichester syncline has been traced eastward till it loses itself beneath the sea.

Mr. Clement
Reid.

Though the mapping of the Hampshire Basin has now been completed, it is probable that a chain of outliers of the Bagshot river-gravels will connect the Eocene of Dorset with that of Bovey Tracey in Devon—indeed, several outliers of this gravel have already been mapped. The amount of Eocene material in the Clay-with-Flints is so great as to point also to a much wider extension of the Eocene strata in every direction in past times.

Mr. Dixon.

In the Cranborne district (Sheet 314) MR. DIXON finds that the marine bed at the base of the Reading Series, mentioned in the last *Summary*,* is persistent throughout the area examined. New fossiliferous localities have been found in the London Clay, the fossils, however, being chiefly in the form of casts. The detailed mapping of the London Clay has brought out the fact that in places where the basement-bed contains much shingle it passes across the baset edges of the Reading Beds on to the Chalk.

In the Maiden Newton district (Sheet 327) MR. DIXON has mapped another Eocene outlier, probably of Bagshot age. It contains flints of every degree of angularity, as well as much Palæozoic material, and subangular fragments of silicified *Cyrena*-limestone, probably derived from Purbeck strata. As the horizon of the Chalk on which this deposit rests is only about 280 feet above the Chalk Rock, it is evident that the overlap of the Bagshot Beds, mentioned in previous *Summaries*, becomes more pronounced as the mapping is extended westward.

OXFORDSHIRE AND BUCKINGHAMSHIRE.

Mr. Blake.

The outliers of Reading Beds at Russellwater Common, Turville Heath, Summer Heath, and Southend Common, Ibstone and Lake End, all north of Henley-on-Thames, have been re-mapped by MR. BLAKE. The first three outliers, which in many places are covered by a thin deposit of loam and flint-pebbles, apparently derived from the local Tertiary Beds, consist entirely of Reading Beds, of little thickness, whereas the Lane End outlier (including Moorend Common) includes five outliers of London Clay above the Reading Beds. Moorend Common is apparently enclosed by four faults as shown on the original Geological Survey Map (Sheet 13). At the brickyard S.-E. of Muzwell Farm, a clean-cut section showed the stratified white and buff sands of the Reading Beds dipping in a south-westerly direction towards the fault on the eastern side of the Common; while on the roadsides south-west of the Common, the Reading Beds dip in a north-easterly direction towards the fault on the western side of the Common. Consequently, it would appear that there must be a considerable fold in the Chalk, which may have contributed to the faulting of this area.

There are faults also at Cadmore-End Common, which have not been previously noticed. One in the northern part runs in

* *Summary of Progress for 1899*, p. 139.

an easterly direction, having a downthrow of the Reading Beds Mr. Blake. to the north, with the Chalk at the surface to the south; another trends in a south-westerly direction, with a downthrow of the Reading Beds to the west.

At Bolter-End, north-westward of the four crossways and south of Cadmore-End Common, an oval-shaped hill, which measures 12 chains in length by 7 chains in width, is entirely composed of flint-pebbles. In a gravel-pit on the eastern part of this hill a vertical section, from 9 to 12 feet thick, has been laid open, without exposing the bottom of the deposit. It presents a mass of closely compacted pebbles, which MR. BLAKE believes to be a pebble-bed of Tertiary age *in situ*, an opinion shared by MR. H. B. WOODWARD when he inspected the section. On the sloping ground around, sand and sandy loam, several feet in thickness, belonging to the Reading Beds and containing much iron sandstone, was seen to intervene between the pebble-bed and the Chalk.

At the brickyard at Kiln Wood, on the west side of Cadmore-End Common, sections of Reading Beds have been exposed, showing mottled clays overlying from 16 to 18 feet of white sand, in which latter impersistent bands of bluish-black sand occurred, varying from about 2 to 4 inches in thickness. A sample of this dark material, taken by MR. H. B. WOODWARD, was examined chemically by DR. W. POLLARD, who reports as follows:—

“The specimen treated with strong hydrochloric acid leaves an insoluble residue of quartz and a little clayey matter. The solution contains alumina, iron, manganese (as peroxide), cobalt, and nickel. Small quantities of lime and magnesia are also present.”

The occurrence of cobalt and nickel in the Reading Beds has not hitherto been recorded.

VOLCANIC SERIES OF THE ISLE OF ARRAN.

During the past year the important discovery by MESSRS. Messrs.
Peach and
Gunn. PEACH, GUNN, and MACCONOCHIE of Mesozoic fossils among the blocks of strata entombed within a large volcanic vent in the Isle of Arran has not only thrown new light upon the former extension of Rhetic, Liassic, and Upper Cretaceous formations over the south of Scotland, but has in the most extraordinary manner furnished evidence as to the geological age of the great series of younger igneous rocks for which this island has been so long famous. MACULLOCH long ago showed that the granite of Arran was probably later than the surrounding red sandstone, for no fragments of it were to be found in these strata. The petrographical resemblance of the assemblage of Arran rocks to those of Antrim and the Inner Hebrides subsequently led to the inference that they not improbably belonged to the same great Tertiary volcanic period.* By the discovery of masses of

* *Trans. Geol. Soc. Edin.*, Vol. II., Part iii. (1873).

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Peach and
Gunn.

hardened Upper Chalk in the great volcanic vent of this island, this inference has now been confirmed in the most singular and unexpected way. This vent broke through a covering of Mesozoic strata, which included a sheet of hard chalk like that of Antrim. The explosion was thus certainly later than the Upper Cretaceous period, and may consequently be unhesitatingly referred to older Tertiary time. The fixing of the age of this vent carries with it the determination of the age of all the associated eruptive rocks. There can now be no room to doubt that the granites, quartz-porphyrries, felspars, pitchstones, diorites, diabases, and basalts are all a connected series of eruptive masses, coeval with the similar assemblages in Antrim, the Inner Hebrides, and St. Kilda.

In previous *Summaries of Progress* reference has more than once been made to the existence of a geological complex, which has been mapped by Mr. Gunn. Lying south of the road leading from Brodick to Shiskine, it is of an oval form, about $3\frac{1}{2}$ miles in length by 3 in breadth. A portion of it is probably the most intricate piece of ground in the whole island. It is bounded on the north by the Machrie Water and on the south by the Clachan Glen. On the east side it extends to the head of Glencloy, and it includes all the highest ground in the island south of the high granite hills, there being three summits (A'Cruach, Beinn Bhreac, and Ard Bheinn), between 1,600 and 1,700 feet above the sea, arranged in a semicircle round the head of Glen Craigag, which glen nearly divides the complex into two equal parts.

This area is made up of fragmental material interpenetrated in all directions, and much altered, by intrusive igneous rocks of various kinds. Much of the fragmental material is in character very like that composing different members of the Old Red Sandstone, and as it occurs in the centre of an area occupied by that formation, it was natural to suppose that these altered rocks were of the age of the Old Red Sandstone. It must be confessed that this view was not free from difficulties, for in many places it was observed that most of the included fragments in the rock were of igneous origin—*e.g.*, quartz-felsites and granites—which do not occur in the Old Red Sandstone of other parts of the island. Some of the rock was also seen to resemble volcanic agglomerate. Patches of marmorised limestone had also been noted in the area, as well as some masses of shale, and of white or light-coloured sandstone, unlike anything observed in the Old Red Sandstone of other parts of the island. In the early part of the year fossils of Rhætic age were obtained by MR. MACCONOCHIE from one of the shale patches, but the relation of this shale to the adjacent fragmental rocks was not easy to explain till MR. PEACH, on a visit of inspection to the ground, came to the conclusion that the main rock of the complex was an agglomerate of igneous origin filling a great neck or volcanic vent.

The fragmentary material can be traced over an area $2\frac{1}{2}$ miles in length, by $2\frac{1}{4}$ in breadth, and it may have once extended

much farther, for it is now surrounded by an almost continuous ring of intrusive igneous rocks chiefly of an acid character.

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Peach and
Gunn.

The general character of the fragmental rock differs much in various places. The matrix often has a great resemblance to that of an ordinary sandstone, and in it are embedded pebbles and blocks of a great variety of igneous rocks—those of an acid character generally predominating. Sometimes, as in Creag Shocach, east of Glenloig House, the rock is a red sandstone which might easily pass for a member of the Old Red series. In several places it is a coarse conglomerate like the characteristic quartzite conglomerate of the Lower Old Red Sandstone. But, on the whole, the included fragments are more or less angular, so that the rock is rather a breccia than a conglomerate, though in only a few places does it assume the character of an agglomerate, entirely made up of igneous material. Fragments of basic lavas are not at all common in it.

Several large patches or fragments of different formations have been enclosed in the vent, some of which, as above stated, have been identified by their fossil contents as being of Rhætic, Lias, and Cretaceous ages. The largest of these, which is of an irregular shape and several acres in extent, contains not only beds of Rhætic age, but grey and red marls of the age of the Lias. This occurs in Allt-an-Dris near Derenenach, and was described with its fossil contents in last year's *Summary of Progress*.

Rather more than a mile to the south-east of this locality another shale patch occurs near the head of Ballymichael Glen, and about half a mile due south to the top of Àrd Bheinn. The exposure in a dry gully on the north-west side of the stream is not large, but the rock may extend for a length of 100 yards, MR. PEACH was the first to obtain organic remains from this shale, and from their general character he pronounced the rock to be Lias. The fossils first obtained were not well preserved, but MR. MACCONOCHIE has since collected a numerous suite of undoubted Liassic specimens in better preservation, which MR. NEWTON has identified. Another patch of shale intensely altered and now of a blue colour, is found about three quarters of a mile south of Glenloig House, but no fossils could be obtained from it.

About 200 yards south of the Lias shale in Ballymichael Glen, and close to the stream, blocks of a cherty or siliceous white limestone occur in the conglomerate, and some may be observed lying in the bed of the stream. These blocks have yielded foraminifera of Upper Cretaceous age. A similar limestone is found in a cave rather more than half a mile to the north-east of Derenenach, some of it much altered by contact with igneous rock, being now a white marble. It contains irregular siliceous lumps (chert or flint) like those which occur in the blocks at Ballymichael Glen. Another place in which white limestone occurs is situated about 550 yards south of Glenloig, and here the limestone was formerly worked, though little is

Messrs.
Peach and
Gunn.

now to be seen. The rock is free from siliceous material, but it is much altered, and it has furnished no organic remains. In the neighbourhood of the Derenenach cave several small swallow holes prove the existence of other patches of limestone which cannot be seen at the surface.

In addition to these patches of limestone and shale some large and small pieces of a light-coloured sandstone have been noticed, perhaps of Jurassic age, but none of them have yielded any fossils. The largest of these masses occurs about 650 yards north-west of Beinn Bhreac, and is 300 yards in length. Some smaller patches are found 100 yards south-west of the Derenenach cave, and 200 yards south of the same cave lies a large mass of a similar sandstone, the boundary of which is not well defined, but it is probably 50 or 60 yards in diameter. Another occurs to the south of the Rhætic Beds. These fragments of Secondary formations (which once covered at least the southern part of the island of Arran) have fallen from above into the vent of a large volcano, which was active at some time later than that of the Upper Chalk.

The Newer Red rocks, which cover so large a portion of the island, are now shown to immediately underlie the Rhætic Beds, and must, therefore, belong to the Trias. In the southern part of the island (the geology of which has been published as Sheet 13), they were classed provisionally as Permian because the lowest member—a false-bedded red sandstone—is similar in character to the Ballochmyle red sandstone near Mauchline, in Ayrshire, which had been considered as of Permian age.

VOLCANIC SERIES OF THE ISLE OF SKYE.

Mr. Harker.

Information gathered by MR. HARKER during the survey of the western part of the Cuillin Hills, as regards the highly complex relations of the Tertiary igneous rocks of Skye, has necessitated some revision of certain parts of the area mapped by him in former years. This has been carried out, with the result that 78½ miles of new boundary-lines have been added to the map. The chief alterations called for were the separation of the intrusive sills from the basaltic lavas on the Strathaird plateau, and the delineation of the boundary between the gabbro on the northern fringe of the Cuillins and the highly metamorphosed and entangled basalts.

The remaining portions of the Cuillin range itself and the neighbouring basaltic tract to the west have been completed. In the former, the chief interest relates to the rocks of the peridotite group enveloped in the gabbro of the south-western Cuillins. These rocks have been mentioned incidentally in a former Report. They have now been examined in detail and found to have considerable importance and interest. The principal mass is a very irregular laccolite which forms the western peak of the Sgùrr Dubh ridge, and extends eastward down An Garbh-choire and northward into the lower part of Coireachan Ruadha. It is not only enveloped in the gabbro, but traversed by countless dykes

and veins of that rock. Indeed, the north-eastern border of the mass, about Allt a' Chaoich, is of a character which defies mapping, showing a gradual transition from peridotite traversed by a network of gabbro veins to gabbro enclosing detached blocks of peridotite. The latter are found in gradually diminishing numbers as far as the shores of Loch Coruisk and Loch Scavaig.

The rocks themselves, which we group as peridotites, are in large part picrites, but there are also abundant types richer in olivine, including pure dunite. Norite occurs locally, and a troctolite, rich in olivine, is often associated with the typical ultra-basic rocks. Two striking features, both indicative of heterogeneity, characterise the rocks as seen in the field. One is the extraordinary prevalence of *débris* of one type of rock enclosed in a matrix of another type; the other is the banded structure which affects in greater or less degree almost the whole of the group, alternating bands differing considerably in petrographical type. One phase of this is the occurrence in the dunite of thin seams composed wholly of picotite.

These plutonic peridotites clearly belong to the oldest intrusions of the Cuillins. There are other ultra-basic rocks, in the form of dykes, which belong to the youngest, since they are found to cut every other rock which they encounter.

Another place where Tertiary igneous rocks have been mapped during the past season is the Isle of Scalpay. The volcanic group is represented here by a small area of basaltic lavas in the southern part of the island. These rocks, resting on Lias to the west, and cut off by a fault to the east, have a thickness of not less than 1,600 feet. In the south-western part of the island an extension of the granite of Skye invades the Torridonian strata, branching out in one place into a succession of sheets. Of the minor intrusions of Scalpay, the most interesting is a group of dykes which belong to the general model of the triple composite dykes of Skye, consisting of granophyre, flanked on each side by basalt. In this outlying area, however, the dykes show great irregularity, in the deficiency of one or other of the component rocks, a sinuous line of outcrop and frequent interruptions of continuity. These imperfections throw considerable light on the nature and origin of the more typical examples in Skye.

Tertiary Igneous Rocks in West Argyllshire.—In the Eas Ruadh glen, six miles south of Oban, numerous dykes, chiefly of basalt, present chilled edges in contact with the andesites. They are split up by newer acid dykes, which are so much weathered that the normal aspect of the rock can only be inferred from the undecomposed rhyolite bombs found in the volcanic rock south of Glen Feochan, in which beautiful flow structure is well shown. As these acid dykes have been injected into the basalt-dykes they may be inferred to be of Tertiary age.

The Craignish promontory, eight miles south of Kilmelfort, displays two compound basalt dykes, of which one runs from Barbreckmore in a N.W. and S.E. direction, and the other a mile

Mr. Harker. to the south-west extends in a parallel direction from the Free Church to Daill, and forms the sole of the road between the two places. In the northern portion of the island of Luing a compound basalt dyke runs in a N.E. and S.W. direction north of Ballahuan. It is found also in the tideway between Luing and Torsay islands.

Pleistocene, including Glacial.

In the course of the field-work last year considerable tracts of Glacial Drift were mapped, and various details were collected which help to increase our knowledge of the history of the Ice Age in Britain. A brief summary of the observations is all that can be given here. In the following narrative a geographical order will be adopted. The English Southern Counties and Midlands will first be taken, then the region of South Wales, and, lastly, the various areas of survey in Scotland from south to north.

SUSSEX.

Mr. Lamplugh's.

The high-level flinty rubble, described in last *Summary of Progress* as having been traced by MR. LAMPLUGH in this county, has been again found by him under the same conditions, though in less quantity, on the higher ground occupied by the Folkestone Beds to the east of the Arun, at Rackham, Parham Park, Kit-hurst, Sullington Warren, and Longbury Hill, forming little plateaux at varying elevations, apparently the remnants of an old surface which sloped westward towards the Arun Valley and also northward from the Downs. The remarkable persistence of this drift on the Folkestone Beds, while it is scarce or absent on the neighbouring formations, seems to be due to the greater height of the outcrop of that group, which, perhaps, thus alone preserves portions of the ancient surface on which the rubble was deposited.

There is the same difficulty on the eastern as on the western side of the Arun Valley in distinguishing between the lower patches of this high-level drift and the higher of the true river gravels, though frequently the presence of fragments of chert, sandstone, &c., in the latter is sufficient to identify them.

Where the escarpment of the Hythe Beds is high, as between Petworth and the Arun, patches of angular cherty rubble, derived from that source, occur as a thin capping on hills of Weald Clay below the escarpment and sometimes half a mile or more distant from it. These usually lie opposite coomb-like indentations in the escarpment, and are probably equivalent to the flinty rubble which occupies a similar though more distant position in regard to the South Downs. Both would require peculiar physical conditions for their production, and are probably the relics of some stage of the Glacial Period.

Gravelly deposits, undoubtedly connected with the erosion of the present valleys, were found under the same conditions as described in last *Summary of Progress*, chiefly in the form of

deltas around the junction of tributary streams with the main valleys, their materials being mainly derived from the high-level drifts. These gravels, in the absence of sections, are sometimes difficult to detect, owing to the deep covering of stoneless sandy wash in the Lower Greensand tract, and of clayey wash in the Wealden area, which form soils indistinguishable from those of the "solid" formations. Mr. Lampugh.

In the vicinity of the Arun, gravels of this class occur at varying elevations, even capping high ground adjacent to the river, as at Lee Farm in the Weald, and at Greatham on the Lower Greensand. They are then, as above stated, scarcely separable from the high-level drift. It is indeed evident that the sub-aerial erosion of the land has gone on without interruption since the period of the high-level drift; there is no trace here of the marine stage recognised at corresponding elevations on the southern side of the South Downs, which therefore probably preceded the earliest drift now existing in the interior.

On the ridges of Weald clay immediately north and south of Gunter's Bridge, one mile north of Petworth, a considerable development of stratified gravel of Wealden material deserves mention, as there seems to be no drainage at present in this locality which will account for it. The gravel occurs, however, at the extreme northern margin of the area surveyed, and may receive explanation from the examination of the tract farther north.

Flints were observed in considerable numbers in the soil of the cultivated lands on the Weald clay, especially in the vicinity of the Arun, but they become scarcer towards the north. A few smooth pebbles of quartzite and two well-rounded and pitted flints, evidently from Tertiary pebbles, were also found under similar conditions. Whether these have been introduced in the process of cultivation or whether they have formed part of the gravels could not be ascertained, but their presence deserves further investigation; if in place, they may indicate a temporary northward inflow through the Arun gorge at some period in the past.

OXFORDSHIRE AND BUCKINGHAMSHIRE.

The mapping of the Loam and Clay-with-Flints on the Chiltern Hills has been continued by MR. BLAKE northwards from Russellswater Common (south-east of Watlington), and from the north of Medmenham to Chinnor Hill. In many places patches of mottled clays and loams are to be seen, which are evidently re-deposited Reading Beds. They are more sandy, not plastic, and much less brilliant in colour than Reading Beds *in situ*, and often contain little fragments of flints. Mr. Blake.

Several patches of Pebble Gravel were mapped and the boundaries of others were revised around the Lane End outlier of Reading Beds. The largest, extending from Dell's Farm to Chequers Farm, N.W. of Lane End, overlies the Chalk, and consists of large and small flint-pebbles, intermixed with

Mr. Blake.

angular and sub-angular flints, in a matrix of yellow, orange, and buff-coloured loam, sand, and clay. The highest part of this gravelly patch is about 622 feet above sea level. Several patches of somewhat similar gravel occur at Cadmore End; while at Kiln Wood, west of Cadmore End Common, pockets of pebbly and sub-angular flint-gravel, ten feet in depth, occur in the white sand of the Reading Beds, which latter present a somewhat wavy and disturbed appearance near the surface, that may possibly be due to glacial action.

Further south from Kensham Farm to the Stockenchurch-road a considerable mass of gravel may be seen. A large pit-section of this deposit shows from 18 to 20 feet of pebbly and subangular flint gravel, intermixed with and overlying re-deposited mottled, crimson, and grey clay, loam, and sand, of the Reading Beds. In the upper part of the section these strata are shown to be distinctly stratified, with gravel above and below them. The Pebble Gravel capping the two outliers of London Clay on the Lane End outlier of Reading Beds consists mostly of small flint-pebbles; but some have been noticed from three to six inches long, intermixed with a few of quartz and lydite, in a matrix of brown sand. In patches of shingly Pebble Gravel near Parmoor the flint pebbles vary from one to three inches in length, and are intermixed with a few of quartz, Lydian stone, and subangular flints, in a matrix of loam and clay.

A large spread of Plateau-gravel extends from Marsh Baldon to Draycot and Burcot. This deposit consists mostly of small flints, rounded and subangular, enclosed in a sandy matrix, with numerous rounded pebbles of quartzite, pink and white quartz, lydite, cherty sandstone, and occasional shell-fragments—much water-worn pieces of *Ostrea* being common. Further west, and also in Nuneham Park, several large areas of loam and clay, full of rounded pebbles of quartzite, quartz, Lydian stone, etc., occur at various levels on the Lower Greensand and on outliers of Gault.

LEICESTERSHIRE.

Mr. Fox
Strangways.

In the east of this county, where MR. FOX STRANGWAYS has been engaged, he has found the Drift to consist chiefly of chalk-bearing Boulder-clay. This deposit caps the higher ground at Knossington, Cold Overton, and Pickwell, but descends into the valley at Owston towards the west and Whissendine towards the north. A broad stretch of country, about a mile or more in width, extending from Burrow, Somerby, and Pickwell eastwards to Ranksborough Hill and beyond, stands up free of Drift. All the valleys cut through the Drift and expose the solid strata, showing that the superficial deposit cannot be of any great thickness. Patches of gravel occur at Cold Overton, Knossington, and Owston, capping the higher ground, but there does not appear to be much sand or gravel at other horizons. The relation of these accumulations to the Boulder Clay is obscure, but they appear to be more or less contemporaneous with it.

According to PROFESSOR JUDD,* these gravels are much con-
torted and disturbed, but since the introduction of roadstone
from the older rocks, the fine sections formerly exposed have
been entirely obliterated. In the *Summary of Progress* for
1899 the erroneous mapping of the Drift in this district, as
shown on Sheet 64, was pointed out. The revision last year has
shown further errors, more particularly to the north of Cold
Overton, where a palpable Upper Lias country with fine sections
in the Rock Bed of the Middle Lias is shown as Drift. Mr. Fox
Strangways.

In the district traversed by the Wreak Valley the Drift is of
considerable diversity, and somewhat unique. There are
certainly two if not three Boulder Clays of different ages, and
also beds of gravel of two or three periods, but it may be doubted
whether there is sufficient evidence for the very numerous sub-
divisions introduced by MR. DEELEY.† He may possibly have
given different names to the same deposit in different localities.
MR. FOX STRANGWAYS, however, reserves his opinion on the
true succession of these deposits until further work has been
done by him in the Trent basin. The present Wreak Valley
appears to traverse an old glacial basin which was more or less
filled up with brickearth and sand before the deposition of the
Chalky Boulder-Clay. It is in the N.E. corner of this district
that the large boulder or drifted mass of oolitic limestone occurs,
300 yards long by 100 yards broad, which was mentioned in the
Annual Report of the Geological Survey for 1892.

In the northern part of the district mapped by MR. FOX
STRANGWAYS there is not much Drift, though a little is found
capping the hills around West Leake. It descends to lower
levels towards the Soar Valley, where it becomes mingled with
post-glacial deposits, and is then difficult to distinguish from
them. The latter become extensive along the lower part of the
river as it approaches its junction with the Trent. The fault
bounding the Lias on the south side at Normanton Hills, which
is shown in the old map 71 S.E., is well seen in the cutting
of the new line of the Great Central Railway.

SHROPSHIRE.

The town of Market Drayton stands on bare Bunter Sand-
stone, but MR. GIBSON has observed that immediately to the
west the Drift appears and increases in thickness so rapidly as
to suggest that the ground on which the town is built is a pre-
glacial bluff of Triassic sandstone, against the western scarp of
which the glacial sands and gravels have been banked up so as
to bring it on a level with the Cheshire plain. To the south of
Market Drayton, round Hinstock, the Drift is thick and consists
largely of loamy sand. To the east and south-east it occurs
in small irregular patches of no great thickness. Near the
head of Coal Brook, however, between Fair Oak and Chipnall Mr. Gibson

* *Geology of Rutland*, in *Mem. Geol. Survey*, fig. 19.

† *Quart. Journ. Geol. Soc.*, vol. xlii., p. 437.

Mr. Gibson. Mill, a considerable thickness of gravel and sand encloses swamps and extensive peat-bogs. The gravel consists largely of small pebbles of Scotch granites, mixed with a few quartzites derived from the Bunter conglomerate. Among the large erratics, which are strewn over the surface of the ground, granites from Southern Scotland are far in excess of those from Cumberland. It would appear that a tongue of ice from the great sheet covering the Cheshire plain carried to this place boulders chiefly derived from the South of Scotland.

The coarse beds of the glacial sands near Market Drayton yield numerous fragments of marine shells, those of *Turritella* being the commonest. They are frequently nearly perfect, but are very fragile.

CHESHIRE.

Mr. Pocock. From the observations of the glacial phenomena in the Macclesfield district, continued by MR. POCOCK last year, he has found it possible to trace out the limits of glacial action in this part of England. No striated surfaces have been detected, the only evidence as to the direction of ice-flow being furnished by the distribution of erratic blocks. Boulders of Millstone-grit, most probably derived from the high ground east of Macclesfield, are scattered over the Lower Carboniferous sandstones of Croker Hill. As the gathering ground does not extend west of a line drawn north and south through Croker Hill, it would seem that the ice followed a more southerly direction than is usual in the north-west of England. This trend is quite in accordance with the disposition of the great physical features which must have controlled the movement of the ice-sheet in this part of the country.

All the hill-tops up to 1,300 feet show, by perched blocks of igneous rocks from Cumberland and Southern Scotland, that they have been overridden by the ice. The first check to the southward progress of the ice seems to have been given by the high ground of Macclesfield Forest, where a dome-shaped hill, a square mile in extent, rises to a height of 1,570 feet. Boulders of Cumbrian and Scottish rocks are found all round the slopes up to a height of 1,330 feet, but no higher. Most likely the summit stood up as a "nunatak," even at the time of greatest glaciation. Two miles further south the ice encountered a more formidable barrier. The conical peak of Shutlingslow stands on an elevated plateau about 1,300 feet above the sea, separated by a deep ravine from the main ridge of the Pennines, the peak itself being 1,658 feet in height. This ravine, known by the name of Wild Boar Clough, contains northern erratics deposited on the flank of the main ridge to a height of 1,100 feet, which shows that the ice must have flowed completely round Shutlingslow. This plateau is, for the most part, free from drift and boulders, but the ice penetrated a shallow depression on the west side of the peak, where the ground sinks to 1,200 feet or less, and left a train of gravel mounds along a line two miles in length. The peak itself,

together with all parts of the plateau which rise above 1,300 feet, Mr. Pocock. are destitute of drift and boulders. Nor is it likely that they ever existed here, since the country is uncultivated moorland, where there would be no occasion to remove boulders, as has been done in the low-lying agricultural districts.

We have now the materials for forming an estimate of the thickness of the ice sheet on the west side of the Pennine Chain. The level of the Trias Sandstone under Macclesfield at its lowest point is 317 feet above the sea; the highest boulder in the same latitude is 1,330 feet. If 100 feet more be allowed for the surface of the ice, the thickness would be 1,113 feet. Probably it was rather less in the southern part of the area, as the limit of boulders around Shutlingslow seems to be some 50 feet lower than it is further north. An estimate of 1,000 to 1,100 feet for the thickness of the ice-sheet in this district will not be far from the truth.

Search was made for any indications of local glaciation, but none were found. Boulders from the main ridge of the Pennines do not seem to have been carried to the westward. Indeed, the northern ice approached so close to the foot of the ridge that it is not likely to have encountered any resistance, as it would have done if an ice-cap had covered the ridge itself.

The Drift in the country round Macclesfield is of two kinds, which may be called respectively Boulder-clay and Fluvio-glacial deposits, the former term being restricted to those deposits which are the direct product of land-ice, and the latter being used for those in which the materials are ice-borne, but the depositing agent was water. It is sometimes difficult to separate the latter from the more modern river-gravels. The Boulder-clay comes to the surface over a small part of the area only, all of which is above the 500-foot contour line. So far as MR. POCOCK has yet observed, all the clays at a lower level belong to the fluvio-glacial series. A thickness of 20 feet or more of Boulder-clay extends up the valley from Sutton to Cleulow Cross, where, at a height of 1,000 feet, the ice passed over the watershed into the basin of the Dane. A section about a mile above the village shows a tough amorphous clay with striated and rounded boulders, many of which are derived from the Lake District Volcanic Series. This appears to be a true till formed under the ice, which came up the valley from the north-west.

Similar deposits cover a considerable area in the valley at Langley, and rise gradually as they are traced up-stream; till at the 1,000-foot level they die out. There are, besides, numerous sheltered spots in the hills where little patches have been lodged in positions which have protected them from subsequent denudation.

The fluvio-glacial deposits cover most of the lower ground, and are found up to a height of over 1,250 feet above the sea. They vary in character from a tough brown, finely-laminated clay, entirely free from boulders, to coarse gravels and boulder-beds, but one and all of them bear marks of deposition by water. Interesting sections of these deposits are given by

r. Pocock. borings in different parts of the country, which illustrate the changeable character of the beds and the small part played by true Boulder clay in the glacial deposits of this region.* At the Macclesfield Asylum 220 feet of Drifts were bored through, with a layer of Boulder clay 44 feet thick in the middle. At the North Cheshire Brewery, a mile distant, two layers of Boulder clay, 12 and 13 feet thick respectively, were encountered in 150 feet of Drift, while at Bollington more than 200 feet of fluvio-glacial deposits were passed through without a single seam of Boulder clay. The peculiar character of these deposits seems to be due to the fact that two rivers, the Bollin and Dean, draining a considerable area of the upland country, emerge on to the lowlands at Macclesfield and Bollington. No merely local melting of the ice-sheet, caused by sub-glacial streams, is sufficient to account for the wide distribution of this kind of drift. The melting must have been general over a wide area, and was probably aided by the two rivers flowing against the ice-foot and liberating large floods of water. Parts of the ice-sheet may still have lingered in the upland valleys, and caused the rivers to flow with greater volume, but the main mass had retreated from the hills, and only occupied the Cheshire plain. The belts of Boulder-clay included in the fluvio-glacial series may indicate oscillations of the ice-front of more or less magnitude, but whether these constitute distinct periods of glaciation comparable to those which obtained in the Alpine region is not clear. The upper parts of these drifts yield evidence of the formation of a lake of considerable extent. Thick beds of finely-laminated brown clay, with occasional banks of sand, can be seen at intervals all along the foot of the hills east of Macclesfield at a level of about 500 feet. They are sometimes covered by a bed of coarse gravel, made up of waterworn stones, local and erratic, which mark the shore line of the lake against the hill slope. The lake seems to have terminated about three miles south of Macclesfield, where a ridge of Trias abuts against the Carboniferous hills above the 500-feet level. Part of the site of the lake is now occupied by a peat-bog called Dane's Moss, not far from the town. On the west side this site is bounded by ridges and mounds of gravel and sand, but on the north there is open ground as far as the Mersey 12 miles distant. Unless the lake was held in by ice on this side, it probably covered the whole of that tract. At present the lacustrine deposit has been traced as far as Bollington, three miles north of Macclesfield. A considerable delta was formed by the river Bollin, where it flowed into the ancient lake. A deposit of gravel 12 feet thick may be seen at Sutton overlying a silty clay above the present stream-level. The gravel consists of well waterworn Cumbrian erratics, mixed with more angular local blocks 6 or 8 inches long, and is no doubt derived from a boulder-clay which has been re-assorted by the stream. The delta is about half a mile wide at this point and 520 feet above the sea. Its

* See Sainter's "Rambles Round Macclesfield."

surface rises gradually as it is traced up stream, and the deposit dies out in the village of Langley a mile higher up. The lacustrine clays show no sign of disturbance by floating ice, so that it is probable that the ice-sheet had retreated from this part of the country at the time of their formation. Mr. Pocock.

The Drifts of the upland country belong to an earlier period than those which have been just described, though they may have been formed during the dissolution of the same ice-sheet. They occur in two groups, one of which (that near Walker Barn) was referred to in the last *Summary of Progress*. The other lies on the plateau at the west side of Shutlingslow peak, and can be best examined in some gravel-pits a short distance north-east of Cleulow Cross. The top consists of coarse water-worn gravel made up of northern erratics and local rocks, underneath which are beds of sand showing beautiful diagonal bedding.

Both groups run across the cols which separate one drainage area from the other. They could not, therefore, have been formed while the present drainage system was in operation; but they are found in precisely those places where the streams would be compelled to flow if the adjacent valleys were filled by ice up to a level of 1,100 or 1,200 feet. Probably the *mer de glace* had sunk down somewhat from its highest limit, and the waters liberated by the melting ice combined with those that flowed off the higher hills to form a tumultuous stream by which the glacial *débris* was heaped up in mounds and ridges in the lowest ground then open. Other mounds of sand and gravel can be seen in the valleys resting on Boulder clay at about the 700-foot level. These have the characters of true kames, and were formed after the present system of streams had become established, but at the same time under glacial conditions. The well-known glacial shell-beds in Macclesfield Cemetery, which were many years ago described by DR. SAINTER and MR. DARBI-SHIRE, are now closed. The level of these deposits is about 450 feet above the sea. The shell-beds that lie at higher levels (1,250 feet) are also covered, but MR. POCOCK had the opportunity of examining some of the specimens which were collected at Cleulow Cross. These were chiefly rolled fragments, and included none which could positively be affirmed to have been *in situ*. The list of species is given by DR. SAINTER in his book on "Rambles Round Macclesfield."

Some instances of buried river-channels have been observed in the course of the survey. The best instance is one recorded by DR. SAINTER, which has been proved by borings in different parts of Macclesfield. The river Bollin at present flows on the east side of the town, at a level of 440 feet above the sea, the Trias sandstone being about 45 feet below the river-bed. Borings in the western part of the town have proved the existence of a trough in the Trias at about 60 feet lower. In pre-glacial times the Bollin must have flowed in a bed 100 feet lower than at present. The other examples may be seen close to the uppermost of the Langley reservoirs near the source of the Bollin. An old channel, filled up with gravelly drift, extending in a

Mr. Pocock. south-westerly direction from the north side of Trentham Bank Wood to Ridgegate Farm, where it joins the present bed of the Bollin. The brook, which is one of the tributaries of the Bollin, has turned aside and cut a new channel through the solid rock at Trentham Bank Wood, joining the main stream a quarter of a mile higher up than at present. A similar instance may be seen at the lower end of the reservoir. Here the Bollin, leaving its old course blocked with Drift, has cut a ravine 100 feet deep in the Millstone-grit nearly 300 yards further to the south.

Mr. Wedd. In the Congleton district the superficial deposits have recently been mapped by MR. WEDD. He finds that the Drift, entering the Biddulph Valley by the gap in the grit ridge at Mossley Village, continues for some distance to be fairly thick and to be steeply banked against the higher Carboniferous ground. But it often thins out unexpectedly, and little or none of it is to be found on much of the low ground in the southern part of the valley where it might be expected to occur. The material consists of sand and clay, clay usually overlying sand, the latter containing shell fragments near Gillow Heath Station. In this district the Drift in places is not more than 20 feet thick, the underlying Keuper Marls being seen in several places, but it becomes thicker to the west of the town of Congleton. Here also clay usually overlies sand, the latter containing shell fragments. Large erratics are far less numerous than in the district to the south.

SOUTH WALES.

Messrs. Strahan, Tiddeman, and Cantrill. The mapping of the superficial deposits in the western part of the South Wales Coal-field and the adjoining districts has been continued by MESSRS. STRAHAN, TIDDEMAN, and CANTRILL. The following summary of the recent results obtained with regard to the glacial geology has been drawn up by MR. STRAHAN, under whose supervision the survey of the district is placed.

In the area surveyed by MR. CANTRILL he has observed proof of a northerly movement of the ice down the valleys on the northern slopes of the Black Mountains. In Cwm Sawdde-fechan there is much till which contains boulders of white grit, though chiefly composed of Old Red Sandstone *débris*; the drift of the Clydach Valley also encloses pieces of limestone, black chert, and white grit. In both cases these boulders must have been carried from south to north. The movement of the main mass of the ice, however, seems to have been along the foot of the slopes in a westward direction, for boulders of the red grits and conglomerates occur some miles east of the point at which these rocks disappear, as previously described (p. 64).

Further evidence of the westerly trend of the ice-flow is furnished by the striæ. On Cefn y Truman and again half-a-mile S.S.E. of Pont Clydach they point N.W., the ice presumably having moved down from the higher ground lying to the S.E. At Carn Cennen they point W. 35° S., and still further west, at the source of the Gwythwel Brook, about S.W. That the upper ridges, if not the actual summits, of the Black Mountains were

enveloped, is shown by the occurrence of Old Red Sandstone Drift within a few feet of the top of Careg yr Ogof (1,924 feet). Striae and bevelled crags occur up to a height of 1,940 feet on Gareg Lâs, and the top of Cefn y Truman (over 1,750 feet) is striated. On Tair Carn there are boulders of Old Red Sandstone at 1,540 feet, while high up in the steep face of the escarpment at Forch Cenlan some till with striated boulders occurs at a height of more than 1,500 feet above the sea, and 600 feet above the foot of the escarpment. It is clear, therefore, that not only did the ice move westwards along the escarpment, and not directly away from it northwards, but that it covered the scarp-face to a high level. These facts can be explained on the supposition that a great body of ice was generated in central Wales, in a region of which the glacial phenomena are not yet known.

Messrs.
Strahan,
Tiddeman,
and Cantrill.

The crest of the Pennant range, which includes Mynydd Gwrhyd, Mynydd-achaf, Carn Llecharth, Mynydd y Gwair, Pen-twyn-mawr, and Craig-fawr constitutes a subsidiary water-parting. In its highest parts it reaches an elevation of more than 1,200 feet, but it is traversed by cols, the lowest of which does not exceed 850 feet. Not only the cols, but much of the range was crossed by the ice of northern derivation, for drift containing Millstone-grit and Old Red Sandstone boulders passed over into the Egel and Lower Clydach valleys, while boulders of these rocks occur within a few feet of the summit of Mynydd Gwrhyd and and Brynmawr. Again, the col between Pen-twyn-mawr and Graig-fawr is occupied by a gravelly Drift loaded with boulders of the same description, and the southern end of Graig-fawr is strewn with scattered blocks. All the valleys, moreover, which lead southwards from this mountain-tract contain an abundance of Boulder-clay in which boulders of a far northern source are common, though the bulk of the material consists of the local Coal-Measures. Here, therefore, we find another example of what has been frequently seen in South Wales, namely, the overflowing of a subsidiary escarpment by the Carmarthen or Brecknock ice-sheet and the augmentation of that flow by the generation of local ice.

Allusion has been made in previous Reports to the fact that the Drift is of a Boulder-clay type near its source, but of a sand-and-gravel type at a distance. This change is well illustrated in the great mass of Glacial material which extends from the Pennant escarpment referred to above to the neighbourhood of Swansea. Not only does it tend to pass in patches into a roughly stratified gravel forming characteristic mounds, but the whole mass assumes a gravelly aspect, while the boulders become more and more rounded as we work southwards until nearly all occur as true pebbles. The change is so gradual that it is impossible to draw a hard-and-fast line between the two types of Drift.

The tendency of the Glacial Deposits to assume the form of ridges and mounds of gravel along the valleys is well exemplified in the Tawe and Loughor valleys. Parts of Swansea are built on typical gravel-mounds, one of them rising to a height of

Messrs.
Strahan,
Tiddeman,
and Cantrill.

more than 200 feet above the river, while another forms the bold eminence occupied by Bryn Melin Park, near Cwm Bwrla, and a third underlies Bryn-hyfyd. Pentre School stands on moundy gravel at a height of 130 feet, and workings in the Hughes' Vein encountered the gravel at a depth of 150 feet below the sea, showing that the deposit is at least 280 feet thick. It is evident, therefore, that Swansea Vale, in the absence of Glacial gravel, would form an inlet of the sea of the same character as the Devon and Cornwall estuaries.

In the Loughor Valley there is a specially fine example of a compound gravel-ridge sweeping round from near Llandilo Tal-y-bont Church by Waun-gron, and thence again northwards, so as to present a convexity to the south, while it encloses an alluvial flat in a concavity towards the north.

Striæ on rock in place are seldom to be found in the Coal-Measures of this neighbourhood, the strata not being of a character to retain them, but some may be seen in one of the Cwm Bwrla quarries, 100 yards south-west of the reservoir. They run slightly south of west, parallel to the Pennant ridge, and indicate an overflow of ice from Swansea Valley along the route now followed by the Great Western Railway. In the Dulais Valley, on the 500-foot contour south-east of Cwm-dulais, there are striæ pointing rather north of west, and nearly parallel to the Dulais Valley, though they are on a plateau. These examples serve to confirm the inference drawn from other evidence, that the Drift had a strong westerly rather than a southerly trend.

MR. TIDDEMAN reports that he has found a solitary boulder of Lias limestone in the Glacial Drift on the south-east point of Caswell Bay, and a pebble of the same rock in the raised beach about 150 yards west of Bacon Hole. As they can hardly have been derived from any known outlier of Liassic rock, he believes that they may point to the late survival of some outlier in the neighbourhood.

DUMBARTONSHIRE.

Mr. Cunningham
Craig.

While completing the map of the Loch Lomond district, MR. CUNNINGHAM CRAIG has made a more detailed examination of the deposits containing marine shells, for which this lake has so long been noted, and some further information has thus been obtained.

At the northern extremity of Inch Lonaig, in a small cliff, the following section is exposed :—

- | | | |
|-------------------------------------|-----------|-----------|
| 1. Soil | - - - - - | 8 inches. |
| 2. Rusty sand (with a few boulders) | - - - - - | 4 feet. |
| 3. Boulder clay | - - - - - | 7 " |
| 4. Fine clays and silts | - - - - - | 13 " |

The upper surface of the Boulder-clay (3) is irregular, as if denuded during the deposition of the overlying sands (2). The upper layers of the fine clays and silts (4), are contorted. It is in

these fine clays and silts that the marine mollusca are found, several horizons having yielded fossils, a fine purplish clay near the bottom of the section being the most fossiliferous band. Mr. Cunningham Craig.

The lower part of the section is much obscured by talus and boulders washed out of the Boulder-clay above. Thus the alternating series of fine yellow and purple and grey clays and silts is usually partly masked. The Boulder-clay is only seen in section for a distance of 50 yards, as the cliff has been denuded to a lower level; another section, however, about 300 yards to the south-west, shows a small pipe or wedge of boulder clay among the marine deposits.

The upper limit of these deposits has been traced at distances varying from 50 to 200 yards inland, and is found to coincide with the 100-foot contour-line. Several openings were made between this level and the cliff section, and in all of these a yellow unstratified sand was disclosed. Half a mile north of Luss, a section on the roadside about 10 feet above lake-level shows similar alternations of stratified clay and silt, but beyond this to the northward no signs of these marine deposits have been detected. This additional evidence tends to confirm the suggestion put forward in the *Summary of Progress* for 1899, p. 166, that these marine deposits represent the 100-foot beach.

It is evident that a recrudescence of the glaciation has taken place while these stratified sands and clays were being deposited at some little distance from the shore. The ice, advancing from the northward, pushed a tongue of boulder clay over the marine deposits, the deposition of this boulder clay causing the contortion of the upper layers of the stratified deposits. The extreme fineness of the material of which these silts and clays are formed, recalls the "rock-flour" derived from the lixiviation of glacial detritus at the foot of a glacier. Subsequently, when the ice retreated, the upper sandy deposits were formed upon the denuded surface of the boulder clay. It appears probable that at the time these marine deposits were being formed the narrower part of Loch Lomond was occupied by ice as far south as Ross point. If this were the case, a comparatively small advance of the ice-front would bring the glacier as far south as Inch Lonaig.

ARGYLLSHIRE.

In the Blackmount region smoothed, ice-worn surfaces and perched blocks have been traced by MR. KYNASTON up to a height of about 2,500 feet. Striated surfaces, however, are not seen, owing to the subsequent weathering of the rock. The later glaciers of the north-eastern part of the Blackmount, especially those descending from Coire Bà and the eastern side of the Clach Leathad range, spread out over Rannoch Moor in a general easterly direction, and among the erratics on the Moor we may now recognise characteristic types of the volcanic rocks of Meall-a-Bhuridh, Sron Creise, &c. The morainic material occurs for the most part as scattered mounds and ridges, divided by more

Mr. Kynaston.

Mr. Kynaston.

or less level tracts of peat-moss and alluvium; but wherever the ground rises, as, for instance, where the granitic mound of Beinn Chaorach, west of Loch Bà, surmounts the general surface of the moor, or on the slopes north of Lochan Mathair Etive, these mounds become thick and numerous, and contiguous with one another. Many of the granite blocks scattered over the moor are doubtless erratics, but a large proportion more probably represent granite that has weathered into huge angular blocks in place. The moraine mounds of the lateral rising portions of the moor resemble those referable to the valley-glaciers, so well seen in many of the glens. Occasionally a more high-level type of morainic material makes its appearance, consisting as a rule of finer material, and forming relatively lower mounds, which somewhat resemble in shape inverted saucers. These occupy elevated tracts and gentle slopes, and are well seen between the ridge of Craig Dubh, two miles S.S.E. of Kingshouse, and the lower crags of Meall-a-Bhuridh, where they cover a tract between 2,000 and 2,400 feet above sea-level. In the burn sections the loose material is sometimes excavated to a depth of at least 20 feet. Similar glacial material has also been observed, at a less elevation, on some of the hills on the west side of Glen Orchy.

The portion of the Moor of Rannoch, lying west of the head of Loch Laidon, is divided roughly into northerly and southerly portions by the broad ridge of Beinn Chaorach. The flatter tracts on either side are occupied by numerous lochs and lochans, and these, judging from the distribution of the alluvial material have evidently undergone, and are still undergoing, extensive silting up, and many were evidently formerly connected to form larger sheets of water. To the north of Beinn Chaorach the moor rises slightly and almost imperceptibly between Lochan Mathair Etive (Loch Mother of Etive) and the Sandy Loch (or Lochan Gaineamhach), the waters on the one side flowing to the west coast down Glen Etive, those on the other side to Loch Laidon, Loch Rannoch, and finally to the east coast.

Occasionally the morainic mounds on the moor assume the form of a low ridge which may be traced in an almost direct line for some distance. One such ridge may be followed for about 2 miles from the west side of the Dubh Lochan in a direction slightly west of north to the river Etive. Possibly this may mark a terminal moraine of the Blackmount glacier.

Around the shores of Loch Creran, and in the lower part of Glen Creran, morainic material in any quantity is entirely absent. The bare rock is almost everywhere at, or close to, the surface, and is polished and striated, the striæ being directed, in every case observed, down the glen. In the lower part of the glen, and on the hill-slopes of the north-west side of the loch, erratics of kentallenite and a coarse augite-diorite are exceedingly common, and often of large size; but neither of these rocks has as yet been found in place in Glen Creran area.

Mr. Symes.

In the district to the south of Oban MR. SYMES has found boulders of granite from the Ben Cruachan mass scattered on

all the islands, but none like the granite of Kilmelfort. Around Mr. Symes. Scamadale Loch, seven miles south of Oban, the striæ on the north side of the glen run in a N.W. and S.E. and also in an E. and W. direction, which is wholly exceptional in this district, where the general glacial movement over a very considerable area was steadily from N. 20 E. to S. 20 W. The anomaly is probably to be accounted for by the different flow of the later glaciation, when the great arms of the glacier followed the lines of valley. At the head of the valley S. of Glen Feochan, four miles from Oban, the striæ coincide with the direction of the glen, which trends N. 27 W. They were presumably produced by a branch from the main ice-sheet.

The older raised beaches of the West of Scotland, which form part of the records of the Ice Age, are well developed in the Oban district. The terrace of the 50-foot beach was traced by MR. SYMES last year round the islands of Luing and Torsay, and on Eilean Gamhna at the mouth of Loch Melfort.

The glaciation of the north end of the Island of Jura was Mr. Peach. studied last year by MR. PEACH. He found that the striæ on the highest cols and crests overlooking the west coast point to the movement of ice across this part of the island from E.S.E. to W.N.W. They are specially conspicuous on the ridge between Grianan Mòr and Ben Garrisdale at heights up to over 800 feet. They probably belong to the period of maximum glaciation. Nests of Boulder-clay are found in the hollows between the hills, usually beneath a coating of peat. There is abundant evidence that, after the maximum glaciation, even the small glens in this part of the island nursed glaciers, seeing that almost every glen has its group of moraines. Some of the moraines reached the sea-level during the period before the elevation of the 100-foot beach, for near the foot of Allt na Conaire moraines merge into the material of that beach.

A well-defined terrace of the 100-foot beach may be seen near the foot of Glen Garrisdale. Along the part of the shore mapped by MR. PEACH the raised beaches are chiefly represented by rock-notches (or *Seter* of the Scandinavian geologists), which correspond to the 100-foot, 50-foot, and 25-foot beaches respectively. The platform of the 50-foot beach is perhaps the most conspicuous, being generally bounded by fine precipices pierced by caves, many of which show signs of having been inhabited at various periods down to the present time, when they are taken advantage of chiefly by lobster-fishers. The rock-notches are generally bare, but sometimes they show a coating of the old shingle.

INVERNESS-SHIRE.

Over the low-lying tract that stretches from Loch Duntel-Mr. Horne. chaig by Tordarroch and Wester Lairgs to Beinn a' Bheurlaich, south of Daviot, evidence has been obtained by MR. HORNE which points to the north-easterly movement of the ice sheet as it streamed outwards from the Great Glen—a conclusion already established by the observations of MR. FRASER and MR. WALLACE

Mr. Horne. of Inverness. Striæ are rarely found on the weathered surfaces of the muscovite-biotite-gneiss, though the trend of the *roches moutonnées* indicates with sufficient clearness the direction of the ice-flow. But on the finely-polished veins of quartz or pegmatite, ice-markings are frequently preserved. West of Tordarroch, the striæ point N. 4° E.; on Meall More east of Farr school-house, E. 20° - 33° N. and N. 20° E.; and on Creagan Bad Each, one mile east of Wester Laigs, N. 25° E.

East of this line of movement, near the watershed between the Nairn and the Findhorn, conclusive evidence has been obtained of the northerly flow of the ice that radiated from the lofty plateau at the head of the Findhorn. On Beinn nan Cailleach—a hill about three miles south-west of Moy Hall—the quartz-schists on the north-west slope, between the 1,500-foot and 1,750-foot contour lines, are finely glaciated. Striæ are readily found, and they point in one uniform direction—N. 12° - 21° W. Along the western margin of the high ground, between Meall More and Creagan Bad Each already referred to, several instances of cross-hatches have been observed, where the striæ point E.N.E. and N.N.W. The north-easterly movement of the ice in Upper Strath Nairn is further proved by the transport of boulders, notably of muscovite-biotite-gneiss and of different types of Old Red Conglomerate.

Boulder-clay is extensively developed on both sides of the watershed between the Nairn and the Findhorn, as, for example, in the Uisge Dubh (Black Water) above Farr House; in the streams draining the north slope of Beinn nan Cailleach and in the various tributaries of the Findhorn near Tomatin. A notable feature of the boulder-clay sections west of Tomatin is the presence of well-striated blocks of Old Red Sandstone, pointing to the existence of an outlier of that formation at no great distance.

Another interesting development of the Drift deposits in Strath Nairn is the morainic gravels on the east side of the valley near Faillie, where they form a remarkable series of parallel ridges, traceable for upwards of a mile, and enclosing lochans or basins of peat. They are strewn with boulders of muscovite-biotite-gneiss, granite, and Old Red Conglomerate.

Mr. Clough. In the tract of western Inverness-shire around Loch Hourn, mapped last year by MR. CLOUGH, the glacial deposits were found by him to consist chiefly of morainic material and boulder-clay. The latter, usually of a brownish colour, is found far up the mountain corries, as well as at lower levels. No stones foreign to the area surveyed have been noticed either in it or in the morainic detritus.

Near the top of Ladhar Bheinn (3,343 feet), on the south side of Loch Hourn, at heights above 2,800 or 2,900 feet, sharp ridges of considerably weathered rock project at the surface, and present no smoothed, distinctly-glaciated contours. In the high region no pieces of rock were found which could not have been derived from localities close by. There are no boulders of pegmatite, nor of siliceous schist like that *in situ* over a large

area a few miles to the east. A deposit, consisting chiefly of **Mr. Clough.** somewhat angular slabs of the local schist, spreads, however, over a considerable extent of ground to the west and south of the hill top, and reaches nearly to the highest point. This deposit somewhat resembles the scree-material, but the inclination of its surface is in many places quite gentle.

Near the top of Beinn na Caillich (2,573 feet) the drift is also of a local character and chiefly composed of slabs of siliceous schist. No pieces of the Ladhar Bheinn schists were noticed, though these rocks cover a great area less than two miles to the east and south-east. On the lower ground around Beinn na Caillich, however, boulders of the Ladhar Bheinn schists, including many pieces of the peculiar rock with hornblende and zoisite, are common, and those which are found in some localities must have been carried in a north-westerly direction.

In the Croulin valley, which descends from Beinn na Caillich, near the mouth of Loch Hourn, two rather extensive stratified deposits, probably of glacial age, have been observed. One of them forms a terrace, or a series of minor terraces, between the 300-feet and the 400-feet contours. Few sections of it are to be seen, but the stratification in some places is nearly horizontal. Perhaps this material was laid down in water that was dammed back by an ice-barrier a little lower down the valley. Another deposit of a more finely bedded character, exposed in an excellent section on the E. side of Croulin burn, between the 800-feet and 900-feet contours, is 80 or 90 feet thick, and is composed of bands of laminated stoneless clay and sand, with other bands containing boulders. The stoneless bands, at least nine in number, vary in thickness from 1 to 12 feet. The bedding is nearly horizontal, but the minor laminae which compose some of the beds are contorted. The slope of the valley in which this deposit lies is steep, and towards the north.

The part of Barrisdale glen above Ambraigh affords a good example of a U-shaped valley, which has been but little altered since the last glaciation. It contains hardly any alluvium, a great part of its floor being formed of smoothed glaciated rock. The side streams have not cut deep channels, but descend in many places over smooth rock ledges.

In the course of **MR. HARKER'S** further investigations in the **Mr. Harker.** Isle of Skye and the neighbouring smaller islands, he has been able to confirm and extend his previous conclusions* relative to the glaciation of that area. He has already pointed out that, while the south-eastern part of Skye was over-ridden by the ice-sheet from the Scottish mainland, the glaciation of the central part of the island has been due wholly to a local ice-cap covering the mountain-district. At the same time the natural radiate out-flow from this local centre was greatly modified by the pressure of foreign ice on that half of the circumference facing the mainland, the flow being diverted westwards round the northern and southern borders of the central mountain district. On the north

* *Summary of Progress* for 1898, p. 179.

Mr. Harker. side the line along which the native and foreign ice marched together followed very nearly the coast-line of Skye, trending first N.W. and then more nearly N. The Isle of Scalpay, though divided from Skye only by a narrow sound, thus comes to show considerable difference, exhibiting the phenomena of a district over-ridden by foreign ice. The glacial striæ follow there a general direction without much regard to the form of the ground. There is no "kettle-moraine," and the drift is never thick except in a few sheltered places. Foreign boulders occur, though sparingly, at all altitudes, instead of being limited to near the sea-level, as is the case on the Skye side of the Sound.

It was pointed out in 1898* how the westward diversion of the great ice-stream from Glen Sligachan was clearly proved by following the course of its mid-streamline, indicated by the preponderance of granite boulders in the drift on the right and of gabbro on the left; and this line was shown to curve westward at Sligachan, and run for several miles near the high-road. It does not, however, run on, as might be expected, to Loch Harport and so to the sea; but before reaching Drynoch Lodge turns S.W. and S., and eventually finds an outlet in Loch Eynort, having thus described a semi-circle from Sligachan. Granite boulders from the Red Hills are abundant in the drift of Glen Eynort, with a much smaller proportion of gabbro. Farther N. and N.W. the latter rock is not found, but granite continues to be abundant, and erratics of it occur at all altitudes, *e.g.*, on the summit of Preshal Beg (1,160 feet), near Talisker.

The left wing of the Glen Sligachan ice-stream found its way by Bealach a' Mhaim (1,150 feet) into the upper part of Glen Brittle, where a few granite boulders are still found among the much more abundant basalts and gabbros. Between here and the mountains must therefore have been pent in the whole of the ice from the northern and north-western sides of the Cuillins. The southern part of the district affords quite similar evidence, attesting the great volume of the interior as compared with the exterior ice-drainage. Only at a later stage, when both the Scottish and the insular ice had greatly shrunk, did the flow from the Skye mountains approximate to a radiating disposition.

ROSS-SHIRE.

Mr. Peach. The glacial phenomena observed in the district of Eastern Ross-shire, mapped last year by MR. PEACH, are regarded by him as nearly all attributable to the later glaciation. At one part of that period the glacier which flowed down the Blackwater seems to have been so powerful as to overlap the highest watersheds between that valley and the streams flowing into Loch Luichart and the Blackwater itself near Garve; for striæ running S.E., and E.S.E., occur on the crests of Meall na Speirag at a height of more than 2,000 feet, and on Beinn Liath Beg, 1,967 feet, both of these elevations rising upwards of 1,200 feet above the bottom

* *Op. cit.*

of the valley. Again on Cairn na Dubh Coille, 1,750 feet, which Mr. Peach overlooks the valley near its great bend to the south, and rises more than 1,200 feet above the valley, the striæ run right across the top, while the whole ridge and sides of the mountain are strewn with huge blocks of augen-gneiss, many of them several tons in weight. The hill itself is built up of "Moine Schist," while the blocks are derived from the augen-gneiss mass which occupies much lower ground to the north and west. Perhaps the most striking feature of the whole region is the remarkable proof supplied by the distribution of the blocks of augen-gneiss as to the direction of movement of the ice during the later glaciation. Immediately beyond the western junction line between the schists and the augen-gneiss, boulders of the latter rock seem to make up most of the moraine-stuff. This preponderance is probably attributable to the large size of the blocks into which the augen-gneiss breaks compared with those of the schist; at any rate the augen-gneiss boulders are by far the most conspicuous constituents of the moraine heaps. Another item of evidence is thus afforded in favour of the idea that a great part of the moraines found on Highland moors and flat-bottomed valleys represent material that was borne forward either within the ice or beneath it, since nowhere in the valley does the augen-gneiss rise into any conspicuous crag above the general level of the ground. That the movement has been generally down the valley admits of no doubt, for, as already stated, from the area of the augen-gneiss innumerable boulders of that material can be followed as a trail right across the low ground and the Cromarty Firth into the Black Isle.*

A few small boulders of augen-gneiss were found in the moraine-stuff to the west of Alt Guid, and even as far as Glasgamich, while MR. GUNN has found them to occur within the watershed of the Broom, still further to the west.† These may have been originally borne westwards by the ice during the period of maximum glaciation, and redistributed by the glaciers of the later glaciation. It has been shown that to the north of the area in question, the ice-shed during the period of maximum glaciation lay far to the east of the present watershed. If this is the explanation of the apparently anomalous disposition of these boulders, they afford the only evidence of the earlier or maximum glaciation in the area.

The glacial phenomena in the higher parts of Strathconon and its tributary valleys have been found to be not so striking as those displayed where the valleys debouch on the low ground, as was described in the last *Summary of Progress*. The striæ found on the ridge immediately north of Strathconon indicate a south-easterly movement of the ice across the ground between Strath Bran and Strathconon, but on passing into the latter glen they are deflected to the eastward, and follow the trend of the valley.

* *Summary of Progress* for 1898, pp. 175-177.

† *Annual Report* for 1896, p. 18.

Mr. Peach.

Very large perched masses of schist, gneiss, and amphibolite are met with at heights of upwards of 2,000 feet on the watershed between Strathconon and Glen Orrin. These indicate an earlier movement of the ice across the present valley-system. To this phase must also be assigned the thick deposit of hard grey till found on the higher hill slopes above the limits of the morainic deposit, and even passing over cols nearly 2,000 feet in height.

CAITHNESS.

Messrs.
Peach and
Crampton.

During the progress of the mapping in Caithness, attention has been given to the remarkably interesting glacial deposits of this county. The lowest and oldest of these deposits has been found in the area surveyed last year by MR. PEACH and MR. CRAMPTON, to be a compact, hard, sandy, dark till with well-glaciated boulders, a large proportion of which are foreign to Caithness. This till, well-known as the Caithness shelly Boulder-clay, is specially characterised by its abundant marine shells. These for the most part are so much shattered and glaciated that they can only be regarded as part of the transported material. The deposit is found in the hollows over the whole area mapped, and often attains a considerable depth. The latest observations of the Geological Survey confirm the conclusions arrived at by previous observers,* that the Caithness till was formed by land-ice, which, after traversing what is now the Moray Firth, crossed the plain of Caithness, in a direction locally varying from W.N.W. to N.W. Numerous instances of striæ were noted last year having this general direction, and boulders of the "Sarclet Conglomerate," a local rock, and the augen-gneiss of Inchbae, in Ross-shire, were traced across the area in trains having the same average trend. Boulders of fossiliferous secondary rocks like those of the Moray Firth Basin, and numerous shell fragments were obtained, but none new to the lists already recorded.†

Overlying the shelly Boulder-Clay where it occurs and overlapping from it on the flagstones, there appears in the eastern part of the area a glacial deposit which varies in colour and in contents according to the local changes in the flagstones. The interstitial clay between the stones is not well compacted, and the included blocks, generally larger than in the older deposit, and mostly of local derivation, are often unglaciated and arranged more or less in lines. Sometimes the deposit is a pell-mell accumulation of flagstone fragments with little or no enveloping matrix. Where the deposit rests on the shelly Boulder-clay the latter usually exhibits an eroded surface, and in certain areas a deposit of sand and gravel intervenes. Shell-fragments and foreign boulders, sometimes found in the lower

* These observations are summarised in a paper read by MESSRS. PEACH & HORNE, *Proc. Roy. Phys. Soc., Edin.*, vol. vi. (1881), pp. 316-352.

† *Loc. cit.*, pp. 339-343.

layers of the newer deposit, are evidently derived from the older. Messrs.
Peach and
Crampton. Where this type of material appears, moraine-mounds also present themselves in such an arrangement as to show that the ice which produced them radiated from certain local centres within the county. In the eastern part of the area a combined glacier emanating from the valley of the River Wick and the Haster Burn seems to have reached the sea in the neighbourhood of Wick and Sinclair's Bay, leaving the low ground studded with its moraines and kames of retreat. It has also had a considerable influence in determining the course of the River Wick, for it made the water to flow round the end of the ice during a pause in its retreat, so that the present small gorge through which the river flows about $1\frac{1}{2}$ mile above Wick is cut on the hill-side instead of across a lower elevation a little to the south. This glacier has similarly affected the course of the river between Bilbster and Watten, while the Lochs of Watten, Windlass, and Kilminster seem to lie in hollows dammed up by its moraines.

In the western part of the area moraines were observed in such positions as to indicate two local glacier-centres. One of these is Spittal Hill, 577 feet high, a little more than 2 miles S.S.E. from Georgemas Junction. Three hollows that hardly deserve the name of valleys radiate from this hill. In the one opening to the north-west a series of rampart-like moraines crosses the main road near Milton Park or Baumskirk House. Across the hollow that trends to the north-east a fine collection of terminal moraines is arranged concentrically. These are well seen from the main road between the Old Hall of Dunn and the road leading down to Bower Station. Good sections of these mounds have been laid open in quarries near the Smithy of Dunn. Near Achnamoin, across the hollow that opens to the south, moraines again occur.

Another local centre further to the north is formed by the Orlig Hill, which rises to a height of 463 feet as a wide elevation about four miles long from north to south, and 3 miles broad. That this comparatively low hill has actually nourished glaciers in seven valleys that radiate from it, seems to be proved by the moraines, often concentrically arranged, which are found at the mouths of these valleys.

A sufficiently large area of Caithness has not yet been mapped to show the extent of this local glaciation, for the phenomena here reported are mostly attributable to the period of shrinkage of the ice. That the local glaciers extended further seaward than the present coast is proved by the occurrence of their deposits in isolated positions on the top of sea stacks, both near Wick and on the coast between Noss Head and Ackergill.

Recent.

As a rule little opportunity is afforded by the Recent Deposits to chronicle new facts of general interest. The following brief notices may serve to show the general nature of the observations made during the past year. They refer to such formations as Head, Blown sand, River alluvia, Raised beaches, and Peat-mosses.

CORNWALL.

Considerable interest attaches to the deposit known as "Head," which overlies the various formations in the southern non-glaciated tracts of England. It is local in origin, and probably represents the subaërial disintegration of underlying and surrounding rocks during a protracted geological period.

Mr.
Wilkinson.

In the district of south-western Cornwall mapped last year by MR. WILKINSON, Head is found at intervals round the coast, generally hanging on to the cliffs. It frequently rests on a thin layer of stratified sand and gravel possibly belonging to an earlier raised beach. It is well developed to the east of Marazion, where it forms a cliff about 40 ft. high. The stones in this deposit are angular and sub-angular, and are arranged more or less horizontally. They consist chiefly of the rocks on which the Head rests. Where the underlying material is slate (Killas) the fragments of it are arranged in somewhat parallel lines, so as to give the appearance of stratification, massive blocks of granite or greenstone occur when either or both these rocks are in place close at hand, and they are grouped in the same way. The matrix of the Head is a tough clay.

In the tract of southern coast-line recently mapped by MR. WILKINSON, no large spaces of the present surface are occupied by raised beaches. Occasionally, as just mentioned, the few feet of stratified material which appears from under the head, may be upraised marine alluvium, and may sometimes extend for a short distance inland under the younger deposit. Other traces of raised beaches may be detected in crevices of the rocky cliffs. The tract between Chyandour and Marazion, north of the railway line, is covered by a deposit of alluvium, under which a foot or two below the surface, the old sea-sand deposits are found.

WESTERN INVERNESS-SHIRE AND ROSS-SHIRE.

Mr. Clough.

In the tract between Loch Duich and Loch Hourn, mapped last year, MR. CLOUGH found portions of the 20-feet raised beach at frequent intervals along the coast, but met with no remains of the higher beaches in that district. Gleann Ghuserein, below Easan Bhuidhe, displays extensive sand and gravel flats, separated by morainic banks and mounds. The margins of the flats sometimes run for considerable distances almost at right angles to the river, and perhaps in most parts they represent,

not lines of erosion, but sides of hollows which previously Mr. Clough. existed on the uneven morainic surface, and which have now been filled with river-borne material.

At Dornie, on Loch Duich, at the back of the 20-feet raised beach, a deposit of sand and gravel may perhaps represent the 100-feet beach, though the surface is now uneven. Further up Loch Long, besides the 20-feet beach, another terrace appears with its top about the 50-feet contour line. In Bundalloch Glen a fine series of gravel terraces slope nearly with the stream; at the foot of the glen the level of the highest terrace is about 100 feet.

CAITHNESS.

In their survey last year MESSRS. PEACH and CRAMPTON confirmed the observation already made as to the absence of raised beaches in Caithness, though these terraces are so abundant in the next counties to the south. Yet the configuration of the coast is eminently favourable both for their formation and preservation. The only marine alluvium met with last year is that of the present beach, the widest expanse of which occurs in Sinclair's Bay. Messrs.
Peach and
Crampton.

Terraces of alluvium were mapped along the larger river courses. Agricultural operations have been carried to such an extent that most of the smaller streams are either cut straight, and are now running in ditches, or in underground drains, so that many smaller patches of alluvium are not now easily detected. On the sites of several fresh water lochs, which have been either partially or wholly drained for shell-marl, considerable areas of alluvium have been laid bare. The Loch of Scarmclate has been partially drained, also the Lochs of Kilminster and Windlass. An old lake once situated to the north of Corsback Hill, in the same neighbourhood as Loch Scarmclate, is now represented by a wide sheet of alluvium. Another example, a little above an acre in extent, near the farm of Borgie about a mile E.N.E. of Watten, which was drained for shell-marl, yielded skulls of *Bos longifrons*.

Peat has been once much more generally spread across the county than now. Large peat-mosses have been removed by cultivation and for fuel. The most extensive tracts mapped last year are the mosses of Kilminster, North Watten, and Bilbster. The peat seems to be made up of the same species of plants as now live on the surface. Birch and hazel were the only trees, observed to be embedded in it. A few bushes of birch, alder hazel, willow, and blackthorn, still survive in hollows above Watten, and a small wood of these trees at Scouthall, a mile further up the Acharole Burn, represents a remnant of the woodland which may have covered wide areas of Caithness at no very distant date.

Sand-dunes are still in course of formation over large areas in Sinclair's Bay, near the mouth of the River Wester. By their advance the river has been dammed back at several periods and lagoons have been formed, which in many cases are now

Messrs.
Peach and
Crampton.

represented by alluvial flats. The process is still going on and is extending seawards. A "Picts-house" near the mouth of the River Wester is only a few feet above the sea-level. The evidence afforded by the eastern part of the area surveyed by MESSRS. PEACH and CRAMPTON tends to prove that at least this part of Caithness has subsided in recent or post-glacial times. MR. CHARLES JOHNSTONE, of Wick, supplied these observers with examples of shell-marl which was dug out of a bed *in situ* beneath low-water mark at Pulteneytown, when the harbour was being deepened. Peat moss with the stools of trees in the position where they grew, is said to be exposed after storms between tide marks on the shores of Sinclair's Bay, a little to the north of Ackergill.

The characteristic bold precipitous coast-line to which the jointed Caithness Flagstones give rise, is well seen both north and south of Wick, the cliffs being indented by caves and "geos" along the joints and fault lines. That the retreat of the cliff-line is comparatively rapid is shown by the cappings of glacial deposits left isolated upon sea stacks. Some of the cliffs, like those at Noss Head and to the south of the Old Wick, rise suddenly out of comparatively deep water, a fact which seems to point to depression of the land since Glacial times.

II.—PETROGRAPHICAL WORK.

The petrographical investigations required in the Geological Survey involve the microscopical and chemical analysis of rocks. This work for England and Scotland has been carried on in the Jermyn Street Museum, under the general charge of MR. J. J. H. TEALL, who conducts the microscopical examination, while DR. POLLARD undertakes the chemical research. The Irish petrography is in the hands of MR. H. J. SEYMOUR at the Dublin office of the Survey. Recent pressure of work has required that a large number of Scottish rocks which had to be determined for the Memoirs now in course of preparation, but could not be undertaken here, should be sent to MR. SEYMOUR, who has completed the examination of a large number of slides and is engaged in the investigation of others.

(I.) IN THE LONDON OFFICE.

The total number of sliced rocks added to the petrographical collections at Jermyn Street during the past year is 757. Of these 78 are English, 644 Scottish, and 35 Foreign. The English collection of sliced rocks at the end of last year numbered 3,343, the Scottish 9,322, and the Foreign 486. Six microscopic slides with corresponding specimens, illustrating DR. EVANS' paper on "Mechanically-formed Calcareous Rocks" (*Quart. Journ. Geol. Soc.*, vol. lvi., p. 559, and five slides, without rocks, illustrating MR. COOMÁRA SWÁMY'S paper

on "Ceylon Rocks and Graphite" (*ibid.*, p. 590), were presented to the foreign collection by the respective authors.

The number of rock specimens gathered by the collectors in Scotland during the past year has been 325, in illustration of the geology of the counties of Banff, Midlothian, Perth, and Ross, and of the island of Arran.

Detailed reports on 229 rocks have been furnished by MR. Mr. Teall. TEALL to the field officers. The petrographical work in connection with the forthcoming Memoir on the North-west Highlands has involved the re-examination of the material collected at various times to illustrate the post-Cambrian igneous rocks and the contact metamorphism produced by them. An outline of these results will be found below.

Chemical analyses of rocks and minerals were conducted in Dr. Pollard. the laboratory of the Survey by DR. POLLARD from January to the middle of July, and from the end of September to the close of the year. During the latter half of July and in August he was engaged in resuming, together with the officers in the field, the examination of the dolomitization of the Carboniferous Limestone of South Wales. Many specimens in illustration of this subject were collected, which, together with those obtained in 1899, it has been impossible as yet to study.

In connection with the re-survey of the South Wales coal-field, it has been determined to institute a series of partial analyses of one or more of the seams in that field, with a view to investigating the causes which have led to the anthracitization of the coal, and thereby estimating, if possible, the area occupied by the steam-coal in the region. For the purposes of this enquiry, which we believe will be of considerable commercial importance as well as scientific interest, a corridor in this building has been specially fitted up with the necessary apparatus.

Among the more important petrographical results obtained at the London office of the Survey during 1900 reference may be made to the researches of MR. TEALL, which have brought to light from the Assynt region a remarkable group of eruptive rocks new to this country and, together with the chemical investigations by DR. POLLARD, have clearly illustrated the interesting succession of metamorphic changes which these rocks and the Tertiary granite of Skye have induced in the surrounding dolomites. A brief account of these researches prepared by MR. TEALL is here given, followed by DR. POLLARD's account of his chemical investigations into the constitution of the same rocks.

THE MARBLES OF ASSYNT.

The re-examination by MR. TEALL of the material collected at Mr. Teall. various times to illustrate the nature of the post-Cambrian igneous rocks of the North-west of Scotland, and the contact metamorphism produced by them, has led to some interesting results, the details of which will be published in the forthcoming Memoir on that region. A brief summary, however, may be given here.

Mr. Teall.

The igneous rocks are represented by the plutonic mass of Cnoc na Sròine, and by various dykes and sills in Assynt and the neighbouring districts. No connected lavas or effusive rocks of any kind are known. The plutonic mass extends from Ledbeg for about five miles in a south-easterly direction, with an average width of about one mile. Cnoc na Sròine (1,306 feet) forms the culminating point. The dominant rock of this mass is a red granite or syenite, remarkably free from ferro-magnesian or any other darker-coloured constituents. It was described by NICOL as a red felspar porphyry, and by MURCHISON as a syenite. DR. HEDDLE pointed out that true porphyritic structure is absent, and that the rock is mainly composed of red felspar, often much stained and decomposed. The essential constituents of this rock are albite or oligoclase-albite, orthoclase and quartz. The two alkali-felspars are sometimes developed as independent constituents, but are more often intimately intergrown, not unfrequently in the form of micro-perthite. Quartz is not an important constituent of the rocks taken as a whole, and is sometimes absent altogether.

The more acid varieties of the red rocks have affinities with the nordmarkites of PROF. BRÖGGER. Taking the mass as a whole, the quartz-syenites (nordmarkites) appear to shade into quartzless syenites, and these again into nepheline-syenites. A typical nepheline-syenite occurs at the foot of the north slope of Cnoc na Sròine. [Slide No. 3086.] It is a coarse-grained rock, composed of large individuals of nepheline and orthoclase, often measuring half an inch or more across, together with biotite and a little accessory melanite. The occurrence of melanite in this rock shows that the nepheline-syenites are intimately connected with the borolanites, which appear to form a basic border to the plutonic mass of Cnoc na Sròine.

In the paper on Borolanite, by MR. TEALL and MR. HORNE,* attention was called to a peculiar type of rock, mainly composed of large individuals of orthoclase and a blue substance, which is evidently an alteration product. This rock apparently forms a kind of pegmatitic vein in the borolanite, east of Aultnacallagach, and is of special interest in connection with a boulder of true nepheline-syenite-pegmatite, found by MR. HINXMAN on the east slopes of Coul More, about five miles west of Cnoc-na-Sròine, and recently sent up for examination from the Edinburgh Museum. In view of what is now known as to the occurrence of nepheline-syenite in the Cnoc-na-Sròine mass there can be little doubt that the boulder has been locally derived, otherwise it might well have been supposed to have travelled from the Christiania district. This block has been cut up and distributed between the Museum of Science and Art in Edinburgh and the Museum of Practical Geology in London. It measured about $9 \times 5 \times 4$ inches. Its component minerals are orthoclase, nepheline, and ægirine. The individuals of orthoclase are of dull, dark, purplish-grey colour, similar to the orthoclase of the pegmatitic vein above

* *Trans. Roy. Soc. Edin.*, vol. xxxvii. (1892), p. 176.

referred to, and the cleavage faces sometimes measure three or four inches across. Nepheline also occurs in large masses measuring one or two inches in diameter. There is no strongly marked idiomorphism about either of these constituents. The ægirine occurs in prisms sometimes two or three inches in length by a quarter of an inch in breadth, penetrating both orthoclase and nepheline. It is sharply idiomorphic in the prismatic zone, with development of the orthopinacoids and prismatic faces. This boulder was probably derived from a pegmatitic vein similar to that occurring in the borolanite to the east of Aultnacallagach.

The relations of albite and nepheline in the various rocks from the plutonic complex of Cnoc-na-Sròine are of special interest. In the quartzose rocks, only albite is found, and the same is true of some rocks without quartz; but the latter often contain both nepheline or its alteration products and albite. As the nepheline increases the albite diminishes, and finally in the nepheline-syenite only orthoclase and nepheline occur.

The plutonic rocks have been intruded into the Durness dolomites which have been profoundly affected in consequence. These altered rocks now contain calcite, dolomite, brucite, diopside, tremolite, mica, forsterite and serpentine. The minerals here mentioned do not occur together in any one specimen, but are distributed irregularly, so as to give rise to different types of rock. Those varieties which consist essentially of carbonates and brucite, are practically identical with the predazzite of the Tyrol. They are found to the north of Cnoc na Sròine in the neighbourhood of the Ledbeg river. A typical specimen of this variety [No. 9208] is a medium-grained, nearly white rock composed of brucite, calcite, and dolomite. The brucite occurs in fibrous or scaly aggregates, which vary from about 0.1 to over 1 mm. in diameter. The larger grains are mostly rounded in outline, but the smaller ones often give square, triangular and hexagonal sections, which strongly suggest the conclusion that the mineral is a pseudomorph after periclase. The carbonates occur as irregular individuals of a somewhat larger size than the brucite. They consist of calcite and dolomite in about equal proportions. The brucite has been isolated and analysed by DR. POLLARD (page 155).

Rocks mainly composed of calcite and forsterite, with a varying admixture of dolomite, sometimes with none at all, constitute another type. A specimen from Cnoc na Sròine [3099] is a fine-grained, nearly white rock, composed of calcite and forsterite. The latter occurs in more or less rounded grains, which vary in size from about 0.2 up to 1 mm. in diameter; the former in large ophitic plates constituting the matrix in which the grains of forsterite are embedded. The forsterite of this specimen has been isolated and analysed by DR. POLLARD (p. 156). The rocks containing calcite and forsterite pass into opicalcites by the serpentinization of the latter mineral.

Other varieties consist of carbonates and diopside, with or

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without tremolite. In these cases it is especially worthy of note that the tremolite is invariably associated with calcite, whereas the diopside is frequently associated with dolomite. This accords with the view that the rocks in question are altered siliceous dolomites, for the development of tremolite ($\text{CaO}, 3 \text{MgO}, 4 \text{SiO}_2$) in dolomite would naturally be accompanied by the formation of calcite, whereas diopside ($\text{CaO}, \text{MgO}, 2 \text{SiO}_2$) could be formed directly by the simple substitution of SiO_2 for CO_2 .

Some exceptional rocks are found in the immediate neighbourhood of the contact with borolanite and augite-syenite in the Ledbeg burn about 500 yards north-east of Ledbeg [9203–9207]. In addition to colourless diopside, mica and carbonates, these rocks contain a green ægirine-augite, identical with that in the augite-syenite. The pyroxene has been isolated from a matrix of calcite and analysed by DR. POLLARD (p. 156). It is aggregated in lumps and patches in a matrix of calcite, either by itself [9203] or in association with the normal colourless diopside [9205]. In the latter case it forms a border to the colourless variety. These peculiar rocks indicate a most intimate blending of the igneous and sedimentary material, accompanied by some interchange of constituents of the kind emphasised by MR. JOHNSTON LAVIS. It is possible to obtain specimens [9206] which show the association of the ægirine-augite with orthoclase in one part and with calcite in another, and the pyroxene-orthoclase aggregate—augite-syenite—shows no sign of chilling at the contact.

The field relations of the marbles of Assynt prove that they are the result of the contact-metamorphism of the "Durness limestone series." This series, as developed at Durness, includes both dolomites and limestones, but in the Assynt district only dolomites have been recognised. The majority of the specimens examined accord with the view that they are metamorphosed dolomites, which contained a variable amount of silica. The development of tremolite, forsterite, and periclase or brucite, in such rocks would naturally be accompanied by dedolomitisation, and as a matter of fact these minerals are always found to be associated with calcite in the rocks under consideration. The general conclusions arrived at as a result of the examination of the marbles of Assynt are—

- (1.) That they are mainly altered dolomites and that the alteration has been accompanied by dedolomitisation, due either to the development of magnesian silicates such as tremolite and forsterite, or to the formation of periclase or brucite.
- (2.) That the opicalcites are the result of the serpentinisation of the forsterite in the rocks containing that material; and, lastly,
- (3.) That in the immediate neighbourhood of the contact in Ledbeg Burn there has been a reciprocal action between the igneous magma and the sedimentary rock, giving rise to identical

pyroxenes in both rocks, such pyroxenes being characterised Mr. Teall. by a combination of the ægirine and diopside molecules.

Similar phenomena are seen in Skye, where the rocks of the Durness series have been marmorized by the Tertiary granite.

The re-examination of the material of the dykes and sills which figure so largely in Sheets 101 and 107, has also led to some interesting results. These belong to two types—dark-coloured hornblende rocks (vogesites), and light-coloured felspathic rocks (felsites). There are also a few intermediate varieties (hornblende-porphyrites), but as a rule the two types are sharply marked. The rocks of the dark melanocratic type are essentially composed of idiomorphic hornblende in a felspathic matrix. As a potash felspar (see DR. POLLARD'S analysis, p. 158) plays an important part in the composition of this matrix, the rocks may be termed vogesites. The specimens of the light-coloured leucocratic type are essentially composed of alkali-felspars and quartz (see analyses, pp. 157–159). Ægirine is sometimes present, and when this is the case (2324) the rocks have decided affinities with the -grorudites of PROFESSOR BRÖGGER.

The following analyses were made by DR. POLLARD in connection with the foregoing investigation. A specimen of marble from the neighbourhood of Ledbeg (9208) contained grains of a mineral which appeared to be brucite or hydromagnesite. To settle this point the mineral was isolated by the use of bromoform (diluted with xylol). It remained floating in the liquid of 2.41 sp. gr. 0.2388 gramme was taken for analysis, and the following results were obtained :—

SiO ₂	-	-	-	-	-	-	-	4
Al ₂ O ₃	}	-	-	-	-	-	-	1.4
Fe ₂ O ₃		-	-	-	-	-	-	
CaO	-	-	-	-	-	-	-	.8
MgO	-	-	-	-	-	-	-	66.0
Loss on ignition	-	-	-	-	-	-	-	31.2
Total								99.8

Calculating the "Loss on Ignition" as water, the ratio of MgO : H₂O = 1 : 1.06.

This leaves no doubt that the mineral is *brucite*.

A green pyroxene was isolated from a specimen [9203] and analysed to see whether, near the junction of the igneous and metamorphic rocks, there had been any inter-action. This point was settled in the affirmative, as will be seen from the following analysis :—

Sp. gr. above 3.28.
 .5032 gramme taken for main analysis.
 .5 gramme taken for Alkalies.
 .329 gramme for FeO.

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						Molecular Ratios.
SiO ₂	-	-	-	-	53.58	.8871
TiO ₂	-	-	-	-	Trace	
Al ₂ O ₃	-	-	-	-	1.32	.0129
Fe ₂ O ₃	-	-	-	-	9.46	.0591
FeO	-	-	-	-	3.36	.0467
MnO	-	-	-	-	.31	.0043
CaO	-	-	-	-	16.82	.3003
MgO	-	-	-	-	11.67	.2891
K ₂ O	-	-	-	-	.20	.0021
Na ₂ O	-	-	-	-	3.31	.0533
Li ₂ O	-	-	-	-	Trace	
Loss on ignition	-	-	-	-	.73	.0405 (as H ₂ O)
					100.76	

Ratio of CaO : MgO = 1.04 : 1.

If we assume the following molecules to be present we have—

(NaK) ₂ Fe ₂ Si ₄ O ₁₂	-	-	-	-	-	25.76
FeFe ₂ Si ₄ O ₁₂	-	-	-	-	-	1.76
FeAl ₂ SiO ₆	-	-	-	-	-	3.03
CaMgSi ₂ O ₆	-	-	-	-	-	62.73
(CaMnFe)SiO ₃	-	-	-	-	-	5.99
SiO ₂	-	-	-	-	-	.73
Loss on ignition	-	-	-	-	-	.73
						100.76

The olivine mineral was separated from three different specimens and analysed [3099, 6743, 6783]. The mineral from No. 6783 (Skye) was analysed to see if it were a diopside or a forsterite, as it seemed possible that the former might have given rise to serpentines. It was, however, found (as will be seen from the analysis) to be a typical forsterite:—

	3099.	6743.	6783.
SiO ₂	42.2	42.6	41.5
Al ₂ O ₃	.8	1.2	.9
Fe ₂ O ₃ *	.5	1.2	1.4
CaO	.3	.6	.3
MgO	57.0	51.2	55.6
Loss on Ign.	.3	3.1	1.2
Total -	101.1	99.9	100.9

* All Iron calculated as Fe₂O₃. State of oxidation not determined.

Ratio of	-	-	-	-	-	MgO : SiO ₂
[3099]	-	-	-	-	-	2.02 : 1
[6743]	-	-	-	-	-	1.8 : 1
[6783]	-	-	-	-	-	2.00 : 1

A partial analysis was made of Specimen No. 6744 to find the Dr. Pollard ratio of lime to magnesia with the following results:—

SiO ₂	-	-	-	-	-	-	15·96
Al ₂ O ₃	-	-	-	-	-	-	·74
*Fe ₂ O ₃	-	-	-	-	-	-	·70
CaO	-	-	-	-	-	-	32·17
MgO	-	-	-	-	-	-	21·43
* Loss on ignition	-	-	-	-	-	-	29·22
Total	-	-	-	-	-	-	100·22

* Calculated as Fe₂O₃. State of oxidation not determined.

This gives the ratio of Lime to Magnesia as 1·08 : 1.

The following analyses of rocks, and felspars isolated from rocks, were made for the description of the rocks to be given in the Memoir on the North West Highlands:—

“Dyke or sill, Cnoc an Droigheim, Assynt, Sutherland, Sheet 107. [2324.] A porphyritic felsite with ægirine allied to grorudite.

The following is MR. TEALL'S description (*Geol. Mag.*, 1900, p. 391):—

“The rock is a pale green felsite, with somewhat obscure indications of porphyritic felspars and decided traces of parallel structure. Under the microscope it is seen to be composed of polysynthetic aggregates, representing original porphyritic alkali-felspars, streaks of micro-crystalline quartz (scarce), and a crypto- or micro-crystalline feldspathic matrix *crowded with acicular microlites of ægirine*. Similar microlites occur in the polysynthetic aggregates, as they do in the phenocrysts in Professor Brögger's grorudite, but they are far less numerous than in the matrix, where they are often so thickly crowded together as to form a felt-like mass. The larger microlites are green, but the smaller ones are colourless; both show the characteristic optic characters of ægirine when isolated from the feldspathic material.”

“Crag west of Loch Coire na Meidhe. Phenocrysts of alkali felspar (microperthite) and oligoclase in a felsitic matrix. This is evidently the dyke facies of the syenite magma.” [8369.]

—	No. 2324.		No. 8369.	
	—	Mol. Ratios.	—	Mol. Ratios.
SiO ₂	75·20	1·2450	76·23	1·2621
TiO ₂	·12	·0015	·12	·0015
Al ₂ O ₃	12·65	·1238	12·91	·1263
Fe ₂ O ₃	1·53	·0095	1·46	·0091
FeO	·28	·0039	·27	·0037
MnO	·10	·0014	Trace.	—
CaO	·60	·0107	·16	·0028
MgO	·26	·0064	·10	·0025
K ₂ O	4·14	·0439	4·03	·0427
Na ₂ O	5·67	·0913	4·34	·0699
H ₂ O 105°	} ·12	} ·0066	·07	—
H ₂ O above 105°			·30	·0166
TOTAL -	100·67	—	99·99	—

Dr. Pollard. From these figures we get the following composition for the rocks :—

2324		8369	
$K_2Al_2Si_6O_{16}$	24.54	$K_2Al_2Si_6O_{16}$	23.86
$Na_2Al_2Si_6O_{16}$	42.08	$Na_2Al_2Si_6O_{16}$	36.81
$Na_2Fe_2Si_4O_{12}$	4.41	$CaAl_2Si_2O_8$	.79
SiO_2	28.04	Fe_3O_4	.86
	99.07	SiO_2	35.09
Unaccounted for—		Unaccounted for—	97.41
TiO_2	.12	Al_2O_3	1.12
FeO	.28	TiO_2	.12
MnO	.10	Fe_2O_3	.87
MgO	.26	MgO	.10
Na_2O	.12	H_2O	.37
CaO	.60		99.99
H_2O	.12		
	100.67		

The ratio of orthoclase to albite is in

No. 2324	- - - - -	1 : 1.81
No. 8369	- - - - -	1 : 1.63

The next analysis was made to determine the composition of the felspathic constituents of Vogesite.

Dyke (Post Cambrian) in thrust limestone, west of Loch Bad nan Calman, Strath Kanaird, Sheet 101 [3069].

The felspar was separated by heavy solution, and the fraction, of sp. gr. between 2.55 and 2.64, analysed with the following results :—

		Mol. Ratios.
SiO_2	61.36	1.0159
TiO_2	.10	.0012
Al_2O_3	15.77	.1543
Fe_2O_3	1.06	.0066
FeO	1.07	.0148
MnO	Trace	
CaO	2.89	.0516
MgO	2.76	.0683
K_2O	6.95	.0737
Na_2O	4.65	.0749
Loss 105°	.28	
Loss above 105°	3.06	1698
Total	99.95	

This would give

$K_2Al_2Si_6O_{16}$	- - - - -	41.19
$Na_2Al_2Si_6O_{16}$	- - - - -	39.45
$CaAl_2Si_2O_8$	- - - - -	1.59
		82.23

Brought forward	-	-	-	-	-	82.23
with the following constituents unaccounted for :—						
SiO ₂	-	-	-	-	-	6.82
TiO ₂	-	-	-	-	-	.10
Fe ₂ O ₃	-	-	-	-	-	1.06
FeO	-	-	-	-	-	1.07
CaO	-	-	-	-	-	2.57
MgO	-	-	-	-	-	2.76
H ₂ O above 105°	-	-	-	-	-	3.06
H ₂ O at 105°	-	-	-	-	-	.28
						99.95

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The ratio of orthoclase to albite would hence be :—
1 : 1.014

The powder under the microscope was cloudy, and appeared to contain a chloritic mineral. This probably accounts for the large amount (17.72 per cent.) of constituents not accounted for.

The porphyritic felspar and the matrix were separated by heavy solution from a rock [8370], and analysed. The fraction of sp. gr. between 2.575 and 2.590 was taken for the porphyritic felspar, and that of sp. gr. 2.613 to 2.630, for the matrix. The locality given is —Burn, quarter of a mile north of top of Sgòunan More [8370]. This felsite, found by MR. PEACH, is intrusive in the Lewisian Gneiss. The following is MR. TEALL's description of the rock (*Geol. Mag.*, 1900, p. 391): " It consists of numerous phenocrysts of pink felspar, usually giving rectangular sections, and measuring about a quarter of an inch across, embedded in a compact light grey felsitic matrix. Under the microscope the phenocrysts are seen to consist of intergrowths of albite and orthoclase, similar to those observed in the plutonic mass of Cnoc na Sròine. The ground-mass is a micro- or crypto-crystalline aggregate of alkali felspar containing a few minute ragged prisms of ægirine. A little free quartz is probably present, but cannot be identified with certainty under the microscope. This rock contains much less ægirine than the typical giorudites, and in this respect more closely resembles the lindöites of PROFESSOR BRÖGGER."

Porphyritic Felspar.			Matrix.	
—	—	Mol. Ratios.	—	Mol. Ratios.
SiO ₂ - -	66.73	1.1050	74.44	1.2325
Al ₂ O ₃ - -	19.05	.1862	14.72	.1440
Fe ₂ O ₃ - -	.86	.0054	1.17	.0073
FeO - -			.17	.0023
CaO - -	Trace.	—	Trace.	—
K ₂ O - -	6.69	.0709	3.99	.0423
Na ₂ O - -	6.59	.1072	5.82	.0937
H ₂ O 105° - -	.17	—	.06	—
H ₂ O above 105° -	.20	.0111	.26	.0144
Total - -	100.29	—	100.63	—

* Calculated as Fe₂O₃, state of oxidation not determined.

Dr. Pollard. Calculated from these analyses the following would be the percentage of the feldspars respectively :—

Porphyritic Feldspars.			Matrix.		
$K_2Al_2Si_6O_{16}$	-	39·63	$K_2Al_2Si_6O_{16}$	-	23·64
$Na_2Al_2Si_6O_{16}$	-	56·41	$Na_2Al_2Si_6O_{16}$	-	49·36
		96·04	SiO_2	-	25·15
Unaccounted for—					98·15
SiO_2	-	2·19	Unaccounted for—		
Al_2O_3	-	·83	Al_2O_3	-	·82
Fe_2O_3	-	·86	Fe_2O_3	-	1·17
H_2O	-	·37	FeO	-	·17
		100·29	H_2O	-	·32
					100·63

The ratio of orthoclase to albite works out to—

In Porphyritic Feldspars 1 : 1·51
In Matrix - - - 1 : 2·21

The porphyritic feldspar consists of an intergrowth of orthoclase and albite having, as will be seen from the analysis, the composition of PROF. BRÖGGER'S kryptoperthite (Zeitsch. Kryst XVI. (1890), p. 529).

From a specimen of Kentallenite obtained by MR. KYNASTON from Alt-an-Sithean, Glen Shira, Argyll (Sheet 45) [8734], the following analysis was made :—

SiO_2	-	-	-	-	-	52·09
TiO_2	-	-	-	-	-	·73
Fe_2O_3	-	-	-	-	-	1·84
Cr_2O_3	-	-	-	-	-	·10
Al_2O_3	-	-	-	-	-	11·93
FeO	-	-	-	-	-	7·11
MnO	-	-	-	-	-	·15
$(Co,Ni)O$	-	-	-	-	-	·07
CaO	-	-	-	-	-	7·84
MgO	-	-	-	-	-	12·48
K_2O	-	-	-	-	-	3·01
Na_2O	-	-	-	-	-	2·04
Li_2O	-	-	-	-	-	Trace
CO_2	-	-	-	-	-	·16
P_2O_5	-	-	-	-	-	·34
Cl	-	-	-	-	-	Trace
$H_2O_{105^0}$	-	-	-	-	-	·11
H_2O above 105^0	-	-	-	-	-	·24
Total	-	-	-	-	-	100·24

Sp. gr. 2·94

An analysis has also been made of an ægirine granulite collected by MR. CUNNINGHAM CRAIG from a locality half a mile E.S.E. of Derry Lodge, Aberdeen. (Sheet 65.) The rock has been thus described by MR. TEALL :—“[8217.] Ægirine granulite. Alkali feldspar, yellow garnet, ægirine and biotite, with magnetite in

sharply-defined octahedra, apatite and probably sphene as accessories. The garnet occurs in more or less idiomorphic crystals, and as aggregates. It resembles in colour the pale tints of the melanite of the borolanites. The ægirine is bright green; it can be definitely determined by examining the powder of the rock. The prismatic fragments give nearly straight extinction, and the greatest axis of elasticity is approximately parallel to the long axis of the fragment."

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SiO ₂	-	-	-	-	-	-	61.79
TiO ₂	-	-	-	-	-	-	.90
Al ₂ O ₃	-	-	-	-	-	-	16.90
Fe ₂ O ₃	-	-	-	-	-	-	3.10
FeO	-	-	-	-	-	-	1.07
MnO	-	-	-	-	-	-	.19
CaO	-	-	-	-	-	-	2.44
MgO	-	-	-	-	-	-	.90
K ₂ O	-	-	-	-	-	-	6.96
Na ₂ O	-	-	-	-	-	-	5.26
P ₂ O ₅	-	-	-	-	-	-	.34
H ₂ O at 105°	-	-	-	-	-	-	.14
H ₂ O above 105°	-	-	-	-	-	-	.29
Total	-	-	-	-	-	-	<u>100.28</u>

(ii.) IN THE DUBLIN OFFICE.

In the Dublin Office of the Survey during the past year 228 rock-slices have been examined and reported on by MR. SEYMOUR, and 119 new slices were prepared and added to the Irish collection of slides which now numbers 2,470. Besides these, 80 slices already in the collection, which had not been previously determined, were examined and named. Of the 228 slides mentioned above, 113 were from Ireland, and the remaining 115 from various parts of Southern Scotland.

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During the recent revision of the Silurian regions of Ireland, attention has been paid to the igneous rocks there developed, and in the ground to the north of Dublin advantage has been taken of a careful microscopical examination of these rocks to bring the maps up to date in regard to their petrography, as this could be done without much expenditure of time in the field. To the south of Dublin, however, in the counties of Wicklow, Wexford and Waterford, the igneous rocks are abundant and so complicated, that as already stated, it has been judged advisable not at present to attempt an adequate revision of the mapping of them, which would involve much time and labour, more urgently needed for the Drift Survey. The following summary will show the general character of the petrographical work last year in Ireland.

The Irish specimens examined by MR. SEYMOUR comprised types of the igneous rocks met with in the revision of the Silurian areas. In County Down (Sheet 49), a large number of dykes prove to be lamprophyres of different varieties according to the predominance of one or other of the ferromagnesian minerals, hornblende, augite, or biotite. A pre-

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liminary account of these rocks was given in last *Summary of Progress* (p. 181), and an examination of more of them was made during the past year, but without bringing to light any additional facts of importance to which special reference need be made. While the rocks are mainly camptonites and kersantites, with and without augite, they include a few which are basalts and dolerites of Tertiary age.

The specimens examined from County Waterford (Sheets 178 and 179) were found to be generally similar in type to those described in last *Summary of Progress*. They are mainly greyish and greenish felsites, the latter sometimes verging on the trachytic andesites. They are sometimes brecciated, and sometimes contain inclusions of other felsites (xenolithic felsites), but with few exceptions are of little interest. Regarding some of the rocks on the south coast of this county, lately regarded as xenolithic felsites, there seems to be reason, as already stated, to doubt whether the fine-grained compact felsite-like base was in all instances truly molten. So far as can be judged at present, this question applies chiefly to those outcrops which occur in the immediate neighbourhood of undoubtedly pyroclastic material. Several specimens of very compact rocks of this kind collected last year were microscopically examined, with the result that the base itself was found to be fragmental, the rocks being, therefore, fine tuffs or ashes. That the fragmental appearance is not due to brecciation subsequent to consolidation seems evident from the complete absence of any trace of fracture *in situ*, in any of the included pieces of lava. Except where complicated by subsequent crushing, the xenoliths in the xenolithic felsites, which have subsequently been brecciated *in situ*, are generally obviously rounded, corroded, or show reaction borders next the magma in which they are embedded, and are distinct from the angular lapilli in the tuffs. Again, in the xenolithic felsites of the Waterford district, the inclusions are all practically in the same state as regards crystallisation, while those of the tuffs vary much in this respect, some being scoriaceous and glassy, others crystalline. In the case of the very compact types it becomes impossible to determine microscopically whether the base is a devitrified felsite or an extremely fine felsitic ash.

Etching with hydrofluoric acid may possibly reveal characteristic etched figures, serving to discriminate between the two classes of rock, and experiments are in progress with this object in view, the rocks selected being those in which the field-evidence is conclusive as to their origin and nature.

True volcanic tuffs occur both at Dunhill Castle (Sheet 179) and in the district to the north thereof, while agglomerates of volcanic origin occur in the neighbourhood of Cullen Castle, a few miles N. of Tramore. These pyroclastic rocks vary considerably in texture, some being coarse agglomerates, others resembling felsites very closely. The lapilli are mainly acid felsites, some scoriaceous, others perlitic, and others finely crystalline. Tuffs generally similar in character occur, amongst other places, at

Kilmurrin Bay, Bunmahon Head, Newtown Head, and east of Mr. H. J. Annestown. The association of these tuffs with andesitic lavas Seymour has already been referred to (p. 56).

The specimens collected from County Wicklow being similar to others already sliced and examined, most of them were readily determinable by mere inspection and comparison. Those which it was found desirable to slice consisted chiefly of compact felsitic-looking rocks, whose precise nature was open to question. Many of these specimens on microscopical examination were proved to be of sedimentary origin, some were cherts, others fine-grained grits and sandstones, all appearing to have been more or less hardened, and thus closely resembling some of the felsites in this area.

Of the 115 slices of Scottish rocks examined during the year, 47 were from the Fifeshire Carboniferous volcanic district, and the remainder (68) from various areas in the Old Red Sandstone and Carboniferous areas of Cantyre, Ayrshire, Renfrewshire, Stirlingshire, Peeblesshire, and Roxburghshire (Sheets 12, 17, 25, 30, 31, and 39 of the Geological Survey Map of Scotland). They resembled closely the similar types of rock described by SIR A. GEIKIE* and DR. HATCH† from neighbouring localities. The rocks from Fifeshire included specimens of the lavas and tuffs, as well as of the intrusive dykes and bosses in the volcanic necks.

The lavas consist of dolerites and basalts, with and without olivine, usually fairly fresh, and of the ordinary characteristic types. In general the tuffs are made up of fragments of basic rocks, finely crystalline to glassy and vesicular in texture, associated with rather abundant quartz-grains and occasionally with a compact pale-coloured material, probably a very fine ash. Pieces of fossiliferous limestone and shale, and, rarely, sandstone also occur in them, the inclusions showing very little signs of metamorphic action. One of the lapilli in the tuffs [8901] is a medium-grained troctolite, composed of basic plagioclase and olivine, the latter much altered and serpentinised. The examination of the stones in the tuffs shows that they belong to the same types of rock as those forming the intrusive dykes in the necks. The average rock is on the borderland of the limburgites, and others vary on either side from olivine-basalts with very little felspar to limburgites proper without felspar-crystals. The most noticeable feature is the constant presence of olivine and the great scarcity of felspar, only two of the slices examined containing the latter mineral in any quantity. Of these two, one is interesting [8912] as being almost identical with Rosenbusch's "Weiselbergit"‡ (augite porphyrite), so far as the ground is concerned, but in the Scottish rock the augites are the conspicuous phenocrysts, and not the plagioclases.

* *Trans. Royal Soc. Edin.*, 1880, vol. xxix., plate xii.

† *Trans. Royal Soc. Edin.*, 1892, vol. xxxvii., pp. 115-126.

‡ Rosenbusch *Mikro. Phys. Massig. Gest.*, p. 501, and plate iv., fig. 1.

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The rocks selected for examination from the various counties in Southern Scotland above enumerated fall, with few exceptions, into two main groups—trachytic and basaltic. The latter are of the usual types, varying from dolerites to basalts. All contain olivine or its platy modification known as iddingsite [5934 and 5935] and are generally fresh and unaltered.

The acid rocks also vary but slightly in composition, but are much more weathered, the alteration being apparently of the lateritic type, and due to the oxidation of the iron-bearing constituents.* The majority are trachytes with and without sanidine phenocrysts, and with a base typically trachytic in texture, that is, made of sanidine microlites in lath-shaped sections showing flow-orientation. Ferro-magnesian minerals (augite chiefly) are present in more or less amount, but are now mostly represented by chloritic or limonitic pseudomorphs. Exceptionally some plagioclase occurs [6640 and 6641], the rocks containing also a larger quantity of a ferro-magnesian constituent (altered to chlorite) and appearing to verge on the lamprophyres.

Another and more common variety of the trachytic rocks is that in which the felspar of the ground, instead of being lath-shaped, is stumpy and short in character and often associated with some interstitial quartz, and with little or no ferro-magnesian mineral. These may be styled orthophyres, to which type they closely approximate. Examples occur near the boundary between Renfrew and Ayrshire (Sheet 22). Many of the foregoing rocks are porphyritic the phenocrysts being sanidine. Glomero-porphyrific structure is common [4205, 6629] and in some instances the crystals are bent into curved forms traversed by cracks, but without noticeable displacement of the various parts.

The most interesting specimens of the trachytes examined are those which contain the feldspathoid nepheline, and are, therefore, *phonolites*. These rocks, two in number [4505 and 4511], from Skelfield Pen, 8 miles S. of Hawick and Pikethaw Hill, Teviot Head, 13½ miles S. of Hawick, are fairly similar to the phonolite of Traprain Law described by DR. HATCH.† The nepheline in idiomorphic crystals is in places moulded on the felspars, and is generally closely associated with a green pleochroic sodapyroxene—ægirine or ægirine-augite. The rocks from the neighbourhood of Stirling Castle [Nos. 6670 and 6672] furnish an interesting example of the formation of a micro-pegmatitic base in an augite-diorite by later intrusion of an acid rock (granophyre). The trachytic rocks have a specific gravity varying from 2.54 [6625] to 2.66 [6645], the average of nine being 2.61. The basalts vary from 2.76 [5935] to 2.95 [4502], the average of four being 2.83.

With reference to the remarks made on p. 56 regarding the occurrence of undoubted tuffs and lavas in the Lower Silurian

* See *Summary of Progress* for 1899, p. 171.

† *Trans. Roy. Soc. Edin.*, vol. xxxvii. (1892), pp. 115-126.

rocks of the eastern and southern Irish counties, the following **Mr. H. J. Seymour.** petrographical notes, prepared at the request of the Director-General by **MR. SEYMOUR**, are here inserted:—

Notes on the Occurrence of Pyroclastic Rocks and Lavas in the Silurian Series of the East and South of Ireland.

Rocks of pyroclastic origin have been recognised in several localities in counties Waterford, Wicklow, and Wexford, while to the north of Dublin others have been found near Balbriggan, and also a few miles inland from that place. In connection with these volcanic rocks a point of interest which may or may not have special significance is, that their outcrops generally appear near the boundary-lines between the Lower and Upper Silurian formations, a feature specially noticeable in counties Wicklow and Wexford, and to a less extent in the Balbriggan area.

Tuffs and ashes are typically developed at Dunhill, Kilmurrin Cove, Newtown Head, and Bunmahon Head, etc., in Co. Waterford, also at Carrickadagan, Co. Wexford, at Duffcarrick, and Ballymoney Fishery in the same county, and at Balbriggan north of Dublin. Agglomerates and volcanic conglomerates and grits are found inland a few miles north-west from Tramore (neighbourhood of Ballyscanlon Lough, Cullen Castle, &c.), and also in massive beds on the shore near Duffcarrick.

Satisfactory evidence of associated undoubted lavas has as yet been procured only at a few places, especially at Knockmahon on the east side of Bunmahon Bay, at Newtown Head, Ballyscanlon Lough, and in the little bay just W. of Bunmahon Head. North of Dublin, good evidence of the occurrence of lavas may be seen. With the exception of the rocks at Newtown Head, the lavas so far examined by **MR. SEYMOUR** are all andesitic in character. The principal type is an andesite with small augite-phenocrysts, such as that at Bunmahon Head and at Ballyscanlon Lough. The pyroxene in these rocks is usually much altered, and frequently converted into epidote. The Balbriggan rock is a calc-diabase, without conspicuous phenocrysts, but when these are present the mineral is a plagioclase. All of these rocks show in the field the characteristic "pillow" or ellipsoidal structure, and are intimately associated with sediments or ashes composed of volcanic detritus. The rock at Knockmahon and that just west of Bunmahon Head are overlain conformably by finely-banded ash, which at the last mentioned locality, as already described (p. 57), has found its way down into the cracks between the "pillows" forming a kind of matrix for the ellipsoids of the lava. The rocks at Newtown Head are pale grey felsites interstratified with tuffs and fossiliferous sediments. They are compact types, and often show beautifully developed spherulitic structure. They have been described in detail by **MR. COWPER REED**.^{*} The tuffs

^{*} *Quart. Journ. Geol. Soc.*, vol. lv., pp. 721 and 763.

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and agglomerates which have so far been examined microscopically are on the whole acid in composition. A few appear to be slightly more basic as, for example, the clastic rocks of Kilmurrin Cove, Duffcarriek, Ballymoney Fishery, and the agglomerates of the Ballyscanlon Lough neighbourhood. In these cases, however, the original character and composition are rather obscured owing to secondary shearing effects, and the development of abundant chloritic material, which give the rocks a more basic aspect than perhaps they originally possessed. The tuffs and ashes of Balbriggan are andesitic in composition. As a typical example of an acid tuff, the Dunhill (Co. Waterford) variety may be cited. Under the microscope the ground is seen to be microclastic, of a pale colour and full of very minute dull coloured indeterminable lapilli. The larger fragments contained in it chiefly consist of felsites, along with a good many pieces of black slate and chloritic patches representing altered material, apparently in some cases basic felsite. The smaller lapilli consist of scarce quartz and felspar crystals, the latter almost completely kaolinized, but sometimes showing traces of repeated twinning. The felsitic lapilli occur in all stages of crystallisation; some are devitrified, others glassy, and others again pumiceous. In several instances the more compact varieties show beautifully developed flow and perlitic structures, which are still distinctly seen in spite of secondary devitrification.

The varieties of pyroclastic rocks which seem to be slightly more basic, are in section seen to be very highly altered, and to contain a quantity of secondary chlorite and calcite. Notwithstanding the shearing which some have undergone, their originally fragmental character is very obvious. The presence of pieces of basic felspars, appears to indicate a more basic constitution than that of the typical acid tuffs described above. As examples, the green tuff of Sheep Island, and that of Ballymoney Fishery may be cited. The coarse agglomerates and tuffs of the Ballyscanlon Lough area contain abundant felsitic fragments, and less commonly andesitic lapilli, embedded in a dark green schistose base containing chlorite and epidote.

The andesitic tuffs at Balbriggan vary from material composed of basic scorïæ and andesitic lapilli, to fine volcanic grits shading off into, and interbedded with black shaly sediments. Some finer grit bands contain fossils. A variety occurs near the Coast Guard Station composed almost entirely of fragmental plagioclase, being, in fact, a typical crystal-tuff.

III.—PALÆONTOLOGICAL WORK.

The Palæontological determinations required for guiding the field-work of the Geological Survey in England, Wales, and Ireland, are made by the staff of Palæontologists under MR. E. F. NEWTON F.R.S., at Jermyn Street; those in Scotland by

MR. B. N. PEACH, F.R.S., at the Survey Office in Edinburgh. MR. NEWTON and his staff are likewise charged with all the palæontological work connected with the Museum of Practical Geology, while MR. PEACH names and superintends the arrangement of the fossils in the Survey collections which are displayed in the Museum of Science and Art, Edinburgh. In the following pages a brief account will be given of the more important parts of the palæontological work of last year.

i. PALÆONTOLOGICAL DEPARTMENT, LONDON.

The ordinary duties of the officers connected with the maintenance of the collection of fossils in the Museum of Practical Geology, and with the registration of specimens received from the Survey and otherwise, although necessarily making the first and a large demand upon their time, are not of such a nature as to need special mention in this place. Between four and five hundred new specimens have been added to those already exhibited in the Museum, and certain important matters of cleaning and remounting have been done.

The Lower, Middle, and Upper Devonian fossils have undergone a thorough revision by MR. H. A. ALLEN, who has taken advantage of the determinations of the REV. G. F. WHIDBORNE, so far as these have been published by the Palæontographical Society. This series of specimens is of especial value on account of its historic interest, many of the specimens having been collected by R. A. C. GODWIN-AUSTEN, J. W. SALTER, W. PENGELLY, and others, while they include many of the type specimens figured by JOHN PHILLIPS in his "Palæozoic Fossils of Cornwall, Devon, and West Somerset." A Catalogue which has been prepared by MR. ALLEN of all the type and figured specimens from the Devonian rocks contained in this Museum will be found on page 196, and it is hoped will prove useful to workers among these older rocks.

A series of *Micrasters* from the Upper Chalk has been prepared and mounted in a special case in the Museum to illustrate the remarkable work recently done on this group of fossils by Dr. ARTHUR ROWE,* who has shown the presence of certain characters of the test which gradually change as the organisms are followed from lower to higher stratigraphical horizons. One of these characters is found in the ambulacral areas. Among the forms of *Micraster* in the lowest parts of the Upper Chalk, the median part of each of the ambulacral areas is smooth, as shown in *M. cor-bovis* and *M. Leskei*, species characteristic of the *Holaster planus* zone; in another form, the middle part of the ambulacral area shows the zigzag suture line more or less distinctly, and this character is commonly met with in *M. præcursor* in the same zone, and sometimes in the zone of *M. cor-testudinarium*. In the last-named zone the zigzag suture is most often deeply depressed with oblique

* *Quart. Journ. Geol. Soc.*, vol. lv., p. 494 (1899).

sides, and the ends of the plates are cushion-like. *Micrasters* with these and certain other characters, and with the test as wide as it is long, have been called *M. cor-testudinarium*. In the still higher zone of *M. cor-anguinum*, the ambulacral area is less depressed, the zigzag groove becomes almost straight and deeply cut, and the cushions are granulated, characters which are found in the common *Micraster* of these beds, *M. cor-anguinum*. The gradual change from one form to another makes it difficult to describe them in words, but in the Museum is shown a series carefully selected from each of the three zones:—1. *Holaster planus*. 2. *Micraster cor-testudinarium*. 3. *M. cor-anguinum*. The specimens from each of the zones are kept separate, so that the variations within the zone may be seen, as well as the gradual change in passing from lower to higher horizons. Thus the smooth ambulacral area is not found above zone 1. The zigzag line is commonly found in zone 1, and sometimes in zone 2, but rarely if ever in zone 3. The deeply divided area is common in zone 2, but rarer in zones 1 and 3. And, lastly, the straight deeply cut and granulated area is the common form of zone 3, but is rarely if ever met with in zone 2, and never in zone 1.

The determination of the series of specimens collected by MR. LAMPLUGH in 1899 from the trial borings at West Brabourne and Penshurst, and including fossils from several horizons of Cretaceous and Oolitic rocks, has occupied much of DR. KITCHIN's time during the year, and the work is not yet completed. Numerous other fossils, received from the Survey officers during the year, have also been determined by the palæontologists, and preliminary reports have in certain cases been supplied to the various officers. Carboniferous fossils from the Isle of Man were determined for MR. G. W. LAMPLUGH, and from South Wales for MESSRS. STRAHAN and TIDDEMAN. A number of obscure specimens from Skye, sent by MR. H. B. WOODWARD, are probably of Rhaetic age; and others are more definitely from the Lias and Inferior Oolite. Lias fossils from Leicestershire have been determined for MR. C. FOX-STRANGWAYS; Oxfordian and Corallian specimens from St. Ives, Elsworth, and other localities in the counties of Huntingdon and Cambridge, for MR. C. B. WEDD; Kimmeridge Clay and Wealden fossils from Dover, and Lower Greensand fossils from Midhurst and Pulborough, for MR. LAMPLUGH; also Chalk fossils from several localities for MR. C. E. HAWKINS. A number of Devonian fossils from Devon and Cornwall have been received from MR. W. A. E. USSHER, which as yet have only partly been worked out by MR. NEWTON.

In the *Summary of Progress* for 1899 (p. 133) an account was given of the discovery by MESSRS. PEACH and GUNN of Rhaetic and Lias fossils in a volcanic vent near Shiskine, Arran, and of a fragment of chert from the same ground, which led MR. PEACH to think that Cretaceous rocks also had once extended over this part of Scotland. Additional specimens have since been obtained, which confirm the determination of Rhaetic

fossils, and careful collecting by MR. MACCONOCHIE has supplied important evidence regarding the occurrence of both Liassic and Cretaceous rocks in the same great vent.

The Lias specimens were nearly all in such a friable condition that it was necessary to harden them with dilute shellac varnish before taking wax impressions, which, reproducing much of the characters of the original fossils, enabled many of them to be specifically determined. About 30 distinct forms have been identified; some of them with more certainty than might have been anticipated. Among these are several small examples of *Ammonites angulatus* and *Gryphæa arcuata*, also *Amberleya acuminata*, *Pleurotomaria tectaria*, *Cardinia Listeri*, *Nuculana Tatei* (*Renevieri*, Tate), *Lima succincta*, &c. Such an assemblage of species points unmistakably to the zone of *A. angulatus*; and none of the forms found militate against the rock being of that age. A further confirmation of this inference is found in the fact that all the specimens seem to have come from one bed only, the little differences in their appearance being almost certainly due to different degrees of decomposition; there is likewise the negative evidence of the absence of characteristic fossils of the *A. planorbis* and *A. Bucklandi* zones.

With regard to the Cretaceous rocks, the presence of which had been so shrewdly suspected by MR. PEACH from the small fragment of chert enclosing obscure Foraminifera, many specimens of hard grey limestone and of fragmentary chert or flint have now been secured. The first piece of the limestone sent to Jermyn Street was sliced for the microscope, and on comparison with sections of Antrim Chalk was found to be like specimens of the latter, in which the whole rock has become saccharoid in character, leaving only faint traces of the organisms, so that it seemed almost certain that the Arran limestone is a similarly altered chalk. Many of the specimens, both of limestone and flint, subsequently collected, showed undoubted organisms, such as sponge-spicules, Foraminifera, &c. A number of sections having been prepared for the microscope, parts of the limestone were found to be unaltered and full of Foraminifera, while some of the flint contained masses of sponge-spicules as well as Foraminifera. The more important fossils noticed were *Inoceramus*-shell (showing prisms), polyzoa, echinoderm-fragments, *Porosphaera globularis*, hexactinellid sponge-fragment, tetractinellid spicules, *Globigerina cretacea*, *Textularia*, &c. That the limestone and flint containing these organisms is of the age of the Chalk seems certain. It may be added that DR G. J. HINDE has been good enough to examine the slides, and agrees that they can only be referred to that formation. A catalogue of types and figured specimens from British Pliocene and Pleistocene strata, preserved in the Museum, has been drawn up by MR. ALLEN, and is printed in the Appendix, p. 182.

On two or three occasions small series of fossils collected during the revision of the Silurian districts in Ireland have been sent to Jermyn Street, and have been reported upon by the

palæontologists there. One set from Stamullen, Co. Dublin, includes examples of *Monograptus priodon*, and *M. Flemingi*, which show that beds of Tarannon or Wenlock age exist in that locality. Two slabs sent from near Gorey, Wexford, were found to contain graptolites referable to the genus *Dichograptus*, and a specimen probably of *Caryocaris Wrighti*, making it tolerably certain that rocks of Arenig age are present in that area.

The Survey is under obligation to MR. V. M. TURNBULL, who has courteously lent a collection of more than 1,300 specimens of fossils, brought together with much care, from the Silurian rocks in the neighbourhood of Haverfordwest. These fossils will be of much value for the purposes of the future re-survey of that district. Their specific determination is therefore desirable, and will shortly be begun.

Assistance has been rendered, as far as possible, to those workers who have wished to examine specimens in the collections of the Museum, or have desired aid in any palæontological work.

Specimens belonging to the Museum have been figured during the year, as shown in the subjoined list:—

Specimens figured in the *Palæontographical Society's* volume for 1900:—

By HENRY WOODS:—

- Limopsis albiensis*, Woods. Four specimens.
- Modiola flagellifera*, Forbes.
- „ *vectiensis*, Woods.
- Septifer lineatus*, Sow. Five specimens.
- Trigonia dunscombensis*, Lycett.
- „ *ornata*, d'Orb.

By DR. WHEELTON HIND:—

- Sanguinolites tricostatus*, Portl.
- „ *oblongus*, Hind.
- „ *plicatus*, Portl. Three specimens.
- Allorisma maxima*, Portl. Two specimens.
- Tellinomorpha jucunda*, de Kon.
- Solenomya primæva*, Portl.
- „ *excisa*, de Kon.
- Solenopsis minor*, M'Coy.
- Conocardium rostratum*, Martin.
- „ *hibernicum*, Sow. Two specimens.
- „ *decussatum*, Etheridge, junr.
- „ *alatum*, de Kon.
- „ *aliforme*, Sow.
- „ *Konincki*, Baily.

Besides the above, the following have been figured:—

By F. A. BATHER, "Geological Magazine," May, 1900, pl. viii-x, p. 193:—

- Edrioaster buchianus*, Forbes.

By DR. WHEELTON HIND, "Quart. Journ. Geol. Soc.," vol. lvi., 1900, p. 47:—

- Palæoneilo carbonifera*, W. Hind.

By E. T. NEWTON, "Proc. Geologists' Assoc." vol. xvi., 1900, p. 496:—

- A remarkable bone from the chalk of Cuxton, possibly referable to the *Rhynchocephalia*.

By A. C. SEWARD, "Trans. Royal Soc. Edinburgh," vol. xxxix., 1900, part 4, No. 34, pl. 1, f. 1, p. 907 :—

Lepidophloios Harcourtii ? Witham.

ii. PALÆONTOLOGICAL WORK IN SCOTLAND.

In Scotland, the palaeontological requirements of the Survey are performed by MR. B. N. PEACH, Acting Palaeontologist, with the assistance of MR. A. MACCONOCHIE and MR. D. TAIT. The total number of specimens of fossils collected last year was 929. These were entered in the list-books and added to the collections. MR. MACCONOCHIE obtained 121 fossils from the Lower Cambrian rocks of Ross-shire; 26 from the Lower Old Red Sandstone of Arran; 5 from the Upper Old Red Sandstone, and 242 from the Calcareous Sandstone of Berwickshire; and in the remarkable volcanic vent of probably older Tertiary age in Arran, he collected 69 fossils from included masses of Rhaetic beds, 129 belonging to the Lower Lias, and 57 from blocks of limestone which, as above shown, are Upper Cretaceous. MR. TAIT collected 51 specimens from the Ludlow, and 169 from the Downtonian rocks of Lanarkshire; 6 from the Lower Old Red Sandstone of Lorne; 6 from the Upper Old Red Sandstone of Fife, and 8 from the Lower Carboniferous rocks of Edinburgh. MESSRS. PEACH and CRAMPTON, while carrying on their work in Caithness, gathered 40 specimens of fossil fishes from the Caithness flagstone series.

MR. PEACH has determined 365 specimens of fossils from the Lower Cambrian rocks of Skye, 872 specimens from the Lower Carboniferous rocks of East Fife, and 200 specimens from the Carboniferous rocks of Arran. DR. CRAMPTON, acting under MR. PEACH, has named 560 specimens from the Lower Carboniferous rocks of Arran.

MR. PEACH, as usual, has made a preliminary examination of the fossils gathered during the year, and with the assistance of MR. TAIT, has distributed certain groups among specialists for determination. The secondary fossils have been sent to MR. E. T. NEWTON at the Jermyn Street Museum; the fossil fishes to DR. TRAQUAIR; the plants to MR. KIDSTON; the ostracods to MR. KIRBY, and the lamellibranchs to DR. WHEELTON HIND. With the assistance of MR. TAIT, he has also selected and sent to DR. WHEELTON HIND a large suite of Carboniferous lamellibranchs from the Scottish collections for study for his monograph on that group.

During the year, DR. TRAQUAIR has named on behalf of the Survey, 146 fossil fishes from the Downtonian rocks, 180 from the Old Red Sandstone, and 101 from the Carboniferous rocks of Scotland. DR. WHEELTON HIND has determined 1,663 lamellibranchs from the Lower Carboniferous rocks of Fife. MR. KIDSTON has named 90 specimens of plants from the Lower Carboniferous rocks of Arran and Fife. Thus, excluding 255 Secondary fossils sent to MR. NEWTON for examination,

4,177 fossils were determined for the Geological Survey of Scotland during the year.

The following notes of the more interesting or important features of the palæontological work of the Survey in Scotland last year have been supplied by MR. PEACH.

Cambrian.—A further search was made by MR. MACCONOCHIE in the Lower Cambrian rocks of Ross-shire, at the locality on Meall a Ghubhais, near Kinlochewe, where he had obtained the specimens of *Olenellus* described in 1894.* The additional specimens obtained by him, however, add little to our previous knowledge, beyond the fact that the fossils of the *Olenellus*-zone are found to include a small brachiopod *Kutorgina labradorica*—a form described by BILLINGS from this zone in America. They comprise several specimens of *Olenellus Lapworthi*, *O. reticulatus*, *Olenelloides armatus*, and larval forms of *Olenellus*.

Upper Silurian.—The Upper Silurian inlier of Lesmahagow, in Lanarkshire, was again searched last year by MR. TAIT. In the last *Summary of Progress* mention was made of the discovery of *Birkenia elegans* in the Ludlow "Ceratiocaris Bed" at Shanks Castle, Logan Water; but the specimen reported on was from a quarried fragment which was not actually obtained directly from its native bed. The latest explorations, however, have supplied several specimens from a band *in situ*. The same band has furnished a specimen of *Thelodus scoticus* which exhibits the eye spots, a new point in the anatomy of this form, as shown in the account given on page 175 by DR. TRAQUAIR. MR. TAIT also found there the chain of rounded, sponge-like bodies which is so common a feature of the Downtonian fish-beds.† On the same horizon MR. FRANK WHITE, of Muirkirk, a local collector, obtained a fine specimen of *Thelodus scoticus* from shales, where it is associated with *Ceratiocaris* at Linn Burn, near the head of Greenock Water, in the Muirkirk district of Ayrshire.

Fishes from two new localities in the Downtonian beds of this inlier were likewise collected by MR. TAIT, one in the Birkenhead Burn, the other at South Field Farm, near Strathavon, where a specimen of *Ateleaspis tessellata* was found, which, as DR. TRAQUAIR shows, has thrown additional light on the structure and affinities of this form. Another feature of MR. TAIT's recent field-work has been the detection of a band with *Glaucanome* occupying a position above the two fish-beds of the Downtonian series in Birkenhead Burn and at Seggholm, along the margin of the Lesmahagow inlier. The stratigraphical succession in this district is thus brought into unison with that which had already been found in the Hagshaw inlier to the south.‡ The remarkable success which has rewarded these latest explorations by the Fossil collector, especially in the newly-discovered locality for

* *Quart. Journ. Geol. Soc.*, vol. l., pp. 661–675, plates xxix–xxxii.

† *Summary of Progress*, 1898, p. 65.

‡ "Silurian Rocks of Scotland," in *Mem. Geol. Survey*, p. 585.

Downtonian fishes near Strathavon, would warrant a further opening up of the strata at this point as well as a renewed examination of some of the places already worked.

Old Red Sandstone.—With a view of following up the discovery of ostracods in the Lower Old Red Sandstone of Lorne, announced last year,* MR. TAIT again made search in the strata of this age, exposed in the railway cutting about a mile from Oban; but the material obtained by him threw no further light on what had previously been ascertained.

MR. MACCONOCHIE, under MR. GUNN'S direction, collected some specimens from the Lower Old Red Sandstone of Arran, in the western part of the island near Dougrie, and from the shore north of Corrie, but he was only able to obtain a few specimen of worm tracks sufficient to prove that the strata were fossiliferous.

Preparatory to the publication of the Memoir on Central and Western Fife and Kinrosshire by the Director-General, MR. TAIT collected a number of specimens from the Upper Old Red Sandstone of the "Howe of Fife," and obtained *Holoptychius nobilissimus*, both from localities whence it had been formerly collected, and also from some new places.

Carboniferous.—The examination by MR. KIDSTON of the plants from the Calcareous Sandstones of the Eastern Borders in the collection of the Geological Survey of Scotland, proved that these strata, which occupy a low horizon in the Calcareous Sandstone group, enclose a peculiar and little-known flora. As a further knowledge of these plants was highly desirable, MR. MACCONOCHIE was sent to obtain additional specimens from certain places which had formerly been successfully examined. MR. KIDSTON, who joined in this search, has been so good as to supply the notes of the results, which will be found on p.

Along with the plant remains from Lennel Braes on the Tweed, near Coldstream, a locality rendered famous by its fossil trees, and from sections on the Whiteadder, near Dunse, MR. MACCONOCHIE unearthed the remains of several air-breathing land-animals. Of these, some belong to the genus *Eoscorpius*, one specimen of which represents the trunk and tail of a large species. Several specimens of millepedes were also found. One of these, belonging to the genus *Archidesmus*, shows the head and several of the anterior segments in excellent preservation. Two other forms were also met with, one belonging to the genus *Archilulus* and the other to *Euphoberia*. A large comb-like organ of *Glyptoscorpius* is in the collection recently made, which likewise includes several specimens of the higher crustacea, belonging to the genus *Anthrapalaemon*, as well as other forms new to science. The great success which has attended these latest explorations indicates that it is from these low and least-known horizons of the Carboniferous system, as developed on the Borders, that the greatest amount of new material is likely to be procured.

* *Summary of Progress*, 1899, pp. 96 and 186.

In view of the forthcoming Memoirs on East Fife and on Arran, a large suite of Carboniferous fossils has been named by MR. PEACH, assisted by DR. CRAMPTON. DR. TRAQUAIR has kindly named the fishes, DR. WHEELTON HIND has examined the lamelli-branches, MR. KIDSTON the plants, and MR. KIRKBY the ostracods.

Note on Carboniferous Plants from Berwickshire. By R. Kidston, Esq., F.R.S.E.

"At the well-known section on the Tweed at Lennel Braes near Coldstream, the following species of plants were observed:—

Alcicornopteris convoluta, Kidston.
Sphenopteris patentissima, Ett. sp.
Lepidodendron sp.
Stigmaria ficoides, Sternb. sp.
Stigmaria ficoides, var. *undulata*, Göpp.

"From the right bank of the river Whiteadder, one-fourth mile west of Edrom House, the following were collected:—

Marchantites, n. sp.
Alcicornopteris convoluta, Kidston.
Sphenopteris sp.
Aphlebia sp.
Lepidodendron sp.

"From the right bank of Whiteadder, three-fourths of a mile below Allanton:—

Marchantites, n. sp.
 • *Aneimites* sp.
Sphenopteris elegans, Brongt.
Alcicornopteris convoluta, Kidston.
Aphlebia sp.
Lepidodendron spitsbergense, Nathorst.
Lepidostrobus sp.
Stigmaria ficoides, Sternb. sp.
Cardiocarpus bicaulatus, Kidston.

"A few specimens still await examination, and among these some stems showing structure, from a road-cutting on the north side of Norham Bridge, from Langton Burn, near Duns, and from Lennel Braes. There are also a few specimens from other localities still unexamined.

"Some of these plants discovered in Berwickshire by MR. MACCONOCHIE are of very great interest. *Lepidodendron spitsbergense* is represented by a fine series of specimens, and though I possess specimens of this plant from other localities in Scotland, I am indebted to the Berwickshire specimens for characters which clearly show that this species is distinct from *Lepidodendron veltheimianum*, Sternb., of which I previously thought it might be a variety.

"The specimen of *Aneimites*, though small, is the first evidence of this genus in British rocks.

"Perhaps the most interesting fossil amongst the plant impressions collected is the new species of *Marchantites*, a genus

which I believe has not been previously found in Carboniferous rocks. The similarity of this fossil to certain recent Liverworts is most striking.

"The specimens showing structure have only been partially examined, but are of great interest, as they come from a horizon so low in the Calciferous Sandstone series. They comprise stems of lycopods and fern petioles. Some of the specimens are well preserved, though others are not in so satisfactory a state of preservation. Only a preliminary examination of this material has been made, but the majority of the plants from Norham Bridge and Langton Burn appear to belong to undescribed species."

Note on Fossil Fishes from the Silurian Rocks of the Lesmahagow District.

By Dr. R. H. Traquair, F.R.S.

"Among the specimens of fishes collected last spring by MR. TAIT in the Ludlow and Downtonian beds of the Lesmahagow District and submitted to me by the Director-General for examination are several which are of very special interest.

"In the first instance, two specimens of Coelolepidæ, one a *Thelodus scoticus* from the Ludlow beds at Shanks Castle, the other a *Lanarkia horrida* from the Downtonian of Birkenhead Burn, show a distinct dark spot on each side of the head near the anterior margin, in a position analogous to that of the orbit in *Pteraspis*, and of the supposed orbit in *Drepanaspis*. If these dark spots, as seems probable, represent the position of the eyes in the Coelolepidæ, their interest from a zoological point of view is obvious.

"A number of additional specimens of the rare and hitherto imperfectly known *Ateleaspis tessellata* have been found, which throw much light on the systematic position of this remarkable genus. The presence of a pair of orbits in the middle of the top of the head, feebly indicated in one of the original specimens, is amply confirmed; a small dorsal fin, situated far back, is likewise seen, and the caudal is shown to be heterocercal, but not bilobate. The affinity of the Ateleaspidæ with the Cephalaspidæ is thus brought out still more strongly than before, but the head-shield is still devoid of cornua, and the general form of the anterior part of the creature reminds us of that in the Coelolepidæ.

"Two additional specimens of *Lasanius problematicus* have occurred in which indications of the soft parts are preserved, and which confirm the observations which I have previously made in this subject in my Memoir on these fishes in the *Transactions of the Royal Society of Edinburgh* for 1899. In that Memoir I figured two small round markings in the front of the head of *L. armatus*, but attached no significance or importance to them, and it is therefore interesting to find that these markings reappear in one of the present specimens of *L. problematicus*, and conse-

quently cannot be accidental. That they represent the orbits is the most probable explanation of their presence, and it may here be pointed out that in their position they remind us of the ring-like structures or markings considered by Dr. Smith Woodward to represent orbits in his remarkable new Ostracoderm genus *Euphanerops*, from the Upper Devonian of Canada.

IV.—PRACTICAL APPLICATIONS OF THE WORK OF THE GEOLOGICAL SURVEY.

It is difficult to give an account of the numerous practical applications of the work of the Survey without entering into details which would be inappropriate here. It may be enough to say that, as in previous years, such applications have been numerous, and that they tend to increase as the nature and utility of the operations of the Survey become more widely appreciated. Enquiries for information on geological matters have been made at each of the offices of the Survey in London, Edinburgh, and Dublin. The subjects on which advice or assistance has been sought have embraced such questions as building-stones, limestone, coal, sand for glass-making, mining, water-supply, well-sinking, soils, sites for houses, and other matters in which a knowledge of geology is required. Information in response to these enquiries has been given as far as possible, personally or by letter. In addition to private individuals, engineers, and other professional men who have sought advice, reference may be made to enquiries received from various Government Departments, particularly the Local Government Board and the Postmaster-General, as well as the London County Council and Urban and Rural District Councils in different parts of the country.

V.—MAPS, MEMOIRS, SECTIONS, &c., PREPARED OR PUBLISHED DURING 1900.

I.—MAPS.

Much time and thought have been given during the past year to the question of printing the maps of the Geological Survey in colour. Up to the present time all these maps, both on the one-inch and the six-inch scale, are coloured by hand. With the advance of geology and the increase of detail in the mapping of the country, the maps become every year more complicated. It is practically impossible to secure either initial correctness of hand-colouring, or subsequent accuracy of revision of the maps when coloured. Every copy of a sheet must be separately checked, and even after the expenditure of

much time and labour, mistakes and omissions escape detection. There can be no doubt that the labour and risk of error would be enormously reduced if colour-printing were adopted. An experiment in this direction was made a few years ago with the map of England and Wales on the scale of four miles to one inch, which was originally prepared in a hand-coloured edition. This map was afterwards prepared and is now obtainable in colour-printed form, and its success justifies the expectation that if the other maps of the Survey were produced by colour-printing their sale and public usefulness would be much increased. The question of ascertaining what system of colour-printing would be most suitable for the special needs of the Survey was entrusted to MR. CLEMENT REID, who, after a careful study of Continental and American maps, has devised a scheme which has been submitted to the Director-General of the Ordnance Survey, under whose auspices certain trials have already been made. It is anticipated that a beginning will immediately be started in this important reform, and that one or more sheets of the 1-inch map may perhaps be issued colour-printed before the end of the present year.

Reference may here be made to the display of a mounted copy of the colour-printed map of England and Wales at the Paris Exhibition, for which the International Jury awarded to the Geological Survey a Grand Prix Diploma.

(i.)—ENGLAND AND WALES.

Manuscript coloured copies of the 6-in. sheets and quarter sheets are made from the field-maps, and are deposited in the offices of the Survey for consultation by the public.

Of these the following, 193 in number, have been prepared and deposited in the Jermyn Street Office:—

Berkshire.—16 S.W.

Brecknockshire.—31 S.E. ; 32 S.W., S.E. ; 33 S.W., S.E. ; 34 S.W., S.E. ; 35 S.W., S.E. ; 36 S.W., S.E. ; 37 S.E., N.E. ; 38 N.W., N.E., S.W., S.E. ; 39 N.W., N.E., S.W., S.E. ; 40 N.W., N.E., S.W., S.E. ; 41 N.W., N.E., S.W., S.E. ; 42 N.W., S.W. ; 43 N.W., N.E., S.W., S.E. ; 44 N.W., N.E., S.W., S.E. ; 45 N.W., N.E., S.W., S.E. ; 46 N.W., N.E., S.W., S.E. ; 47 N.W., N.E. ; 48, N.W. ; 50 N.W., N.E.

Buckinghamshire.—40 N.E., S.E.

Cheshire.—46 N.W., S.W., N.E., S.E. ; 47 N.W., S.W., S.E.

Cornwall.—30 N.W., S.W. ; 71 S.E.

Devonshire.—111 N.E.

Dorsetshire.—9 N.W. and S.W., N.E., S.E. ; 10 N.W., S.W. and S.E. ; 15 N.W., N.E., S.W., S.E. ; 16 N.W., N.E., S.W., S.E. ; 17 N.W., S.W. ; 25 N.W., N.E. ; 26 N.W., N.E. ; 30 S.E.

Glamorganshire.—9, 10, 11, 12, 16, 17, 18, 19, 25, 26, 27, 28, 33, 34, 35, 36, 39, 40, 41, 42, 43, 44, 45, 46, 47, 48, 49, 50, 51 and 52.

Hampshire.—8, 9, 44, 54, 62, 63, 67, 70, 71, 72.

Isle of Man.—1, 2, 3, 4, 7, 8, 9, 10, 11, 12, 13, 14, 15, 17, 18.

Leicestershire.—33 N.W., S.W. ; 38 S.E. ; 39 S.W., S.E.

Middlesex.—10 S.E. ; 15 N.E. ; 16 N.W., N.E., S.W.

Monmouthshire.—4, 6, 7, 11, 12, 13, 17, 18, 19, 22, 23, 24, 27, 28, 29, 32, 33, 34, 38.

Oxfordshire.—47 N.W., S.W. ; 49 N.W., N.E., S.E. ; 52 N.W., N.E., S.W., S.E.
 Rutland.—8 S.E. ; 12 N.E.
 Staffordshire.—10 N.E. ; 25 N.E., S.E. ; 26 N.W., S.W. ; 32 N.W.
 Sussex.—22, 34, 35, 36, 50.
 Wiltshire.—72, 77.

One-inch Maps New Series. Published in 1900.

Sheet 187, Huntingdon. One edition with Drift. By A. C. G. CAMERON.

Sheet 203, Bedford. One edition with Drift. By A. C. G. CAMERON.

Sheet 231, Merthyr Tydfil. Two editions, with and without Drift. By A. STRAHAN, W. GIBSON, and T. C. CANTRILL.

Sheet 316, Havant. One edition with Drift. By W. WHITAKER, C. REID, and C. E. HAWKINS.

Ditto, New Edition.

Sheet 232.—Abergavenny, with additions.

The following one-inch New Series Maps are in the hands of the engraver:—123, 261 and 262, 298, and 314.

(ii.)—SCOTLAND.

One-inch Maps.

One sheet of the one-inch map has been published during the past year:—

No. 27, by S. B. WILKINSON, embracing the north part of the Island of Islay, part of Jura, and part of Colonsay.

The following five sheets are far advanced in preparation, viz. :—

Sheet 21, embracing the northern half of the Isle of Arran, the south end of Bute, with the Little Cumbrae and nearly the whole of the Great Cumbrae and parts of the coast of Ayrshire and Cantyre. It is confidently anticipated that this Sheet will be issued during the summer.

Sheet 37, containing the country on both sides of the upper half of Loch Fyne.

Sheet 38, showing the country on either side of Loch Lomond westwards to Glencoe and the Gare Loch and eastwards to Callander and Fintry.

Sheet 55, embracing the Perthshire Highlands from Dalnaspidal to Loch Tay, and from Loch Rannoch to the Spital of Glenshee and Dunkeld.

Sheet 65, containing the portion of the Grampian Mountains and the valley of the Dee from Linns of Dee to below Ballater and from Glen Gairn to Clova.

(ii.)—IRELAND.

Manuscript duplicate copies of the following six-inch maps have been made, and have been deposited in the Dublin office for public reference:—

Co. Carlow - Sheets, 3, 4, 5, and 8.

Co. Tyrone - Sheet 16 and part of Sheets 14 and 15.

One-inch Maps published in 1900.

The following new editions of one-inch sheets, showing the revision of the Silurian rocks in the north and east of Ireland, have been issued during the past year—viz., Sheets 37, 38, 47, 50, 57, 80, 87, and 90. While the present *Summary* is in preparation two additional sheets, Nos. 67 and 79, have been published. A large number, comprising all the Silurian ground to the north of Dublin, are now with the engraver. Those of the central and south-eastern counties are in course of preparation for the engraver, and will, as far as possible, be published this year.

II.—SECTIONS.

One Sheet of Vertical Sections (No. 83) of shafts in and below the Pennant Grit in the Taff, Aberdare, and Rhondda Fach Valleys, of the South Wales Coal-field, has been published. Two other sections are in the hands of the lithographers. These Sheets of Vertical Sections, which were being printed off in 1899, were unfortunately destroyed by a fire at the printers. They have now been re-drawn and re-engraved, and are nearly ready for issue.

III.—MEMOIRS.**A. — OFFICIAL.****1.—England and Wales.**

During the year four Memoirs have been published, namely:—

"Summary of Progress of the Geological Survey of the United Kingdom for 1899," pp. 214. Price 1s.

"The Cretaceous Rocks of Britain." Vol. I. The Gault and Upper Greensand of England. By A. J. JUKES-BROWNE, with Contributions by WILLIAM HILL, pp. 499. Price 9s.

"The Geology of the South Wales Coalfield." Part II., the Country around Abergavenny. By AUBREY STRAHAN and WALCOT GIBSON, with Notes by J. R. DAKYNS and PROF. W. W. WATTS, pp. 103. Price 2s.

It is intended that as each District or Sheet of this important region is completed a descriptive account of its geology shall be published as nearly as possible simultaneously with the map. This series of pamphlets will eventually form a detailed and exhaustive Monograph of the South Wales Coalfield.

"The Geology of the Country between Atherstone and Charnwood Forest." By C. FOX-STRANGWAYS, with Notes by PROF. W. W. WATTS, pp. 102. Price 2s.

The following Memoirs are in different stages of progress:—

"The Geology of the Isle of Man." By G. W. LAMPLUGH. (*In slip proof.*)

"Guide to the Geology of London." By W. WHITAKER. 6th Edition. (*At the printers.*)

"The Cretaceous Rocks of Britain," Vol. II. A. J. JUKES-BROWNE, with Contributions by WILLIAM HILL. (*At the printers.*)

"The Water Supply of Berkshire." By J. H. BLAKE, with Contributions by WILLIAM WHITAKER. (*In slip proof.*)

- "The Geology of the Country around Exeter." By W. A. E. USSHER, with Notes by J. J. H. TEALL. (*In slip proof.*)
- "The Geology of the Country around Southampton." By CLEMENT REID. (*At the printers.*)
- "The Geology of the Country around Kingsbridge and Salcombe." By W. A. E. USSHER. (*In preparation.*)
- "The Geology of the South Wales Coal-field." Part III., The Country around Cardiff. By A. STRAHAN and T. C. CANTRILL. Part IV., The Country around Pontypridd. By A. STRAHAN, R. H. TIDDEMAN, and W. GIBSON. Part V., The Country around Bridgend. By R. H. TIDDEMAN and T. C. CANTRILL. (*In preparation.*)
- "The Geology of the Country around Reading." By J. H. BLAKE. (*In preparation.*)
- "The Geology of the Country around Torquay." By W. A. E. USSHER. (*In preparation.*)

2.—Scotland.

The Memoir on Central and Western Fife and Kinross, by the DIRECTOR GENERAL, alluded to in last *Summary of Progress* as nearly ready for the printer, has since been published. It forms a volume of viii., 284 pages, and is sold at 5s. 6d.

Other Memoirs are in progress, and some are far advanced. The important Memoir on the North-West Highlands has demanded more time than was anticipated, but it is now almost all written, and it is hoped that it will be published early next year. The Memoir on Eastern Fife, which has been undertaken by the Director General, may possibly be issued by the end of this year. Several Sheet-memoirs are in hand, and every effort is being made to prepare and issue them simultaneously with the Sheets of the map which they describe, or as soon as possible thereafter.

It may be added that in order to furnish material for the illustration of some of these memoirs, MR. ROBERT LUNN, the Clerk in the Edinburgh Office, last year visited the islands of Arran and Cantyre, and took 148 photographs of rock-sections and scenery.

B.—NON-OFFICIAL.

The following is a list of the non-official publications of the members of the staff of the Geological Survey of the United Kingdom during the year 1900:—

BLAKE, J. H.—"Excursion to Silchester." *Proc. Geol. Assoc.*, vol. xvi., pp. 513-516.

GEIKIE, SIR A.—"De la Co-opération Internationale dans les Investigations Géologiques." *Congrès Géol. Internat. viii^e Session.*

——. "Outlines of Field Geology." 5th Edit.

——. "Elementary Lessons in Physical Geography." 4th Edit.

——. "Primer of Geology." 3rd Edit.

——. "Primer of Physical Geography." 3rd Edit.

——. "Obituary Notice of the Duke of Argyll." *Nature*, vol. lxii., p. 13.

GIBSON, W.—"On Rapid Changes in the Thickness of the Coal Measures in North Staffordshire." *Rep. Brit. Assoc. for 1900.*

——. "The Upper Coal Measures Surrounding the Margins of the North Staffordshire Coal-fields, and their Bearing on the Extension of the Coal-field to the West." *Trans. Inst. Min. Engineers*, vol. xx. pp. 73-78.

GOODCHILD, J. G.—“The Soils of Cumberland.” In Hodgson’s “Flora of Cumberland” (*Carlisle*).

——. “Solar Energy in Relation to Ice.” *Proc. R. Phys. Soc. Edin.*, vol. xiv., pp. 137-154.

——. “Some Notes on a Rock Allied to Limburgite, near North Berwick.” *Ibid.*, pp. 155, 156.

——. “On the Maintenance of the Earth’s Internal Heat.” *Ibid.*, pp. 157, 158.

ALFRED HARKER. — “Notes, Geological and Topographical, on the Cuillin Hills, Skye.” *Scottish Mountaineering Club Journ.*, vol. vi., pp. 1-13.

——. “Magnetic Disturbance in the Isle of Skye.” *Proc. Camb. Phil. Soc.*, vol. x., pp. 268-278.

——. “Igneous Rock Series and Mixed Igneous Rocks.” *Journ. of Geol.*, vol. viii., pp. 389-399.

HILL, J. B., and H. KYNASTON. — “On Kentallenite and its Relation to other Igneous Rocks in Argyllshire.” *Quart. Journ. Geol. Soc.*, vol. lvi., pp. 531-557.

JUKES-BROWNE, A. J. — “Note on a Boring through the Chalk and Gault near Dieppe.” *Geol. Mag.*, Dec. 4th, vol. vii., pp. 25-28.

KITCHIN, F. L. — [Description of a new Cretaceous *Terebratulina*.] Appendix B in A. W. Rowe, “The Zones of the White Chalk of the English Coast,” pt. 1. *Proc. Geol. Assoc.*, vol. xvi., pt. 6, pp. 355-358, pl. viii., figs. 1-5.

——. “Jurassic Fauna of Cutch; The Brachiopoda.” *Palæontologia Indica*, ser. ix., vol. iii., pt. 1, pp. 1-87, pl. i.-xv.

LAMPLUGH, G. W. — “On Some Effects of Earth-movement on the Carboniferous Volcanic Rocks of the Isle of Man.” *Quart. Journ. Geol. Soc.*, vol. lvi., pp. 11-22.

——. “Note on the Age of the English Wealden Series.” *Geol. Mag.*, Dec. 4, vol. xii., pp. 443-445.

NEWTON, E. T. — “On a remarkable bone from the Chalk of Cuxton, possibly referable to the *Rhynchocephalia*,” Appendix to paper by G. E. Dibley. “Zonal Features of the Chalk Pits in the Rochester, Gravesend, and Croydon areas.” *Proc. Geol. Assoc.*, vol. xvi., 1900, pp. 496-499.

REID, C. — “Geology of Hampshire.” In “Victoria County History.” fol. London.

SEYMOUR, H. J. — “On the occurrence of a Blue Amphibole in a Hornblende Kersantite from Co. Down.” *Geol. Mag.*, Dec. 4, vol. vii., pp. 257-260.

STRAHAN, A. — “On the Conditions under which the Plants of the Coal Period grew.” (Joint discussions, Sections C. and K.) *Rep. British Assoc. for 1900* (Bradford).

TEALL, J. J. H. — “The Natural History of Phosphatic Deposits.” (Presidential Address.) *Proc. Geol. Assoc.*, vol. xvi., pp. 369-387.

——. “On Nepheline-Syenite and its Associates in the North-West of Scotland.” *Geol. Mag.*, Dec. IV., vol. vii., pp. 385-392.

TIDDEMAN, R. H. — “On the Age of the Raised Beach of Southern Britain as seen in Gower.” *Geol. Mag.*, Dec. IV., vol. vii., pp. 441-443.

USSHER, W. A. E. — “The Devonian, Carboniferous, and New Red Rocks of West Somerset, Devon, and Cornwall.” *Proc. Somerset Arch. and Nat. Hist. Soc.*, vol. xlv.

WEDD, C. B. — “The Outcrop of the Corallian Limestones of Elsworth and St. Ives.” *Rep. Brit. Assoc. for 1900* (Bradford).

WOODWARD, H. B. — “A Greywether at South Kensington.” *Geol. Mag.*, Dec. IV., vol. vii., pp. 543, 544.

——, A. R. HUNT, and W. A. E. USSHER. — “Excursion to Newton Abbot, Chudleigh, Dartmoor, and Torquay.” *Proc. Geol. Assoc.*, vol. xvi., pp. 425-442.

APPENDIX A.

CATALOGUE of TYPES and FIGURED SPECIMENS from BRITISH
PLIOCENE and PLEISTOCENE STRATA preserved in the
MUSEUM of PRACTICAL GEOLOGY, London.

By H. A. ALLEN, F.G.S.

Each specimen is entered under the name given to it when first figured. When the author's name is placed in brackets (Phillips), it refers only to the species and not to the genus. The letter **T** indicates that the specimen is the type of the species. The figures in square brackets [7009], correspond to the number in the Museum Register.

The following abbreviations are employed:—

Mem. Geol. Survey: Memoirs of the Geological Survey of the United Kingdom.

Mon. Pal. Soc.: Monograph of the Palæontographical Society, London.

Quart. Journ. Geol. Soc.: Quarterly Journal of the Geological Society of London.

U.F.B.: Upper Freshwater Beds.

PLIOCENE.

PLANTÆ.

Trapa natans, Linnæus.

C. Reid, Mem. Geol. Survey, Pliocene, 1890, p. 168 (Text figure).
Forest Bed. [7362] Mundesley.

ANIMALIA.

HYDROZOA.

Hydractinia circumvestiens, S. Wood.

C. Reid, Mem. Geol. Survey, Pliocene, 1890, p. 40 (Text figure).
Coralline Crag. [7365] Sutton.

ECHINODERMATA.

Brissus scillæ, Agassiz.

E. Forbes, Mon. Pal. Soc., 1852, pl. ii., f. 4., p. 15.
Coralline Crag. [7359] Iken, Suffolk.

Spatangus reginæ, Gray.

E. Forbes, Mon. Pal. Soc., 1852, pl. ii., f. 2, p. 14.
Coralline Crag. [7358] Orford, Suffolk.

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BRYOZOA.

Fascicularia aurantium, M. Edwards.

C. Reid, Mem. Geol. Survey, Pliocene, 1890, p. 20 (Text figure).
Coralline Crag [7366] Suffolk.

LAMELLIBRANCHIATA.

Kellia corbuloides, Philippi.

A. Bell, Trans. R. Geol. Soc., Cornw., vol. xii., 1898, pl. iii., f. 26 *a, b, c*,
p. 163.
Pliocene. [6477] St. Erth, Cornwall.

Pisidium astartoides, Sandberger.

C. Reid, Mem. Geol. Survey, Pliocene, 1890, pl. v., f. 11 *a, b*.
Forest Bed (U.F.B.) [C.R. 17] West Runton.

GASTEROPODA.

Columbella erythrostoma, Bonani.

A. Bell, Trans. R. Geol. Soc. Cornw., vol. xii., 1898, pl. i., f. 1, p. 139.
Pliocene. [C.R. 227] St. Erth.

Hydrobia Steini, E. von Martens.

C. Reid, Mem. Geol. Survey, Pliocene, 1890, pl. v., f. 8.
Forest Bed (U.F.B.) [C.R. 13] West Runton.

Limax modioliformis, Sandberger.

C. Reid, Mem. Geol. Survey, Pliocene, 1890, pl. v., f. 6 *a, b*.
Forest Bed (U.F.B.) [C.R. 777] West Runton.

Lithoglyphus fuscus, Pfeiffer.

C. Reid, Mem. Geol. Survey, Pliocene, 1890, pl. v. f. 9 *a, b*.
Weybourn Crag. [C. R. 1042] East Runton.

Littorina gibbosa, Etheridge and Bell.

A. Bell, Trans. R. Geol. Soc. Cornw., vol. xii., 1898, pl. iii., f. 1, p. 154.
Pliocene. [6475] St. Erth.

Nematura runtoniana, Sandberger.

C. Reid, Mem. Geol. Survey, Pliocene, 1890, pl. v., f. 10 *a, b*.
Forest Bed (U.F.B.) [C.R. 787] West Runton.

Odostomia magna, Etheridge and Bell.

A. Bell, Trans. R. Geol. Soc. Cornw., vol. xii., 1898, pl. ii., f. 15, p. 146.
Pliocene. [6476] St. Erth.

Paludina gibba, Sandberger.

C. Reid, Mem. Geol. Survey, Pliocene, 1890, pl. v., f. 4 *a, b*.
Forest Bed (U.F.B.) [C. R. 762] West Runton.

Triton heptagonum (Brocchi).

S. V. Wood, Mon. Pal. Soc., 1848, pl. iv., f. 8, p. 41.
Coralline Crag. [7361] Gedgrave.

Turbo (Senectus) Newtoni, Etheridge and Bell.

A. Bell, Trans. R. Geol. Soc. Cornw., vol. xii., 1898, pl. ii., f. 17, p. 155.
Pliocene. [6479] St. Erth.

Valvata fluviatilis, Colbeau.

C. Reid, Mem. Geol. Survey, Pliocene, 1890, pl. v., f. 7 *a, b*.
Forest Bed (Derived specimen in Leda Myalis Bed). [C.R. 826]
West Runton.

PISCES.

Abramis brama, Linnæus.

E. T. Newton, Mem. Geol. Survey, Vert. Forest Bed, 1882, pl. xviii.,
figs. 19, 20, p. 126.
Forest Bed (U.F.B.) [C.R. 957] West Runton.

Acanthias vulgaris, Risso.

E. T. Newton, Mem. Geol. Survey, Vert. Forest Bed, 1882, pl. xix, f. 8,
p. 131.
Weybourn Crag. [C.R. 981.] East Runton.

Acerina vulgaris ? Cuvier.

E. T. Newton, Mem. Geol. Survey, Vert. Forest Bed, 1882, pl. xviii.,
f. 9, p. 121.
Forest Bed (U.F.B.) [C.R. 914] West Runton.

Acipenser sp.

E. T. Newton, Mem. Geol. Survey, Vert. Forest Bed, 1882, pl. xix.,
f. 6, p. 129.
Forest Bed. (King Coll.) [7350] Mundesley.

Anarrhichas lupus, Linnæus.

E. T. Newton, Mem. Geol. Survey, Vert. Pliocene, 1891, pl. x., f. 4 a, b,
p. 91.
Coralline Crag. [2187] Gedgrave.

Carcharodon megalodon, Agassiz.

E. T. Newton, Mem. Geol. Survey, Vert. Pliocene, 1891, pl. ix., f. 13 a, b,
p. 103; C. Reid, Mem. Geol. Survey, Pliocene, 1890, p. 14 (Text figure).
Red Crag. [3100] Foxhall Hall, Suffolk.

Carcharodon Rondeleti, Mueller and Henle.

E. T. Newton, Mem. Geol. Survey, Vert. Pliocene, 1891, pl. ix., f. 4 a, b,
p. 104.
Red Crag. [7320] Boyton.

Cetorhinus maximus, Linnæus (Spine of clasper).

E. T. Newton, Mem. Geol. Survey, Vert. Pliocene, 1891, pl. ix., f. 12 a, b,
p. 102.
Red Crag. [7319] Woodbridge.

Chrysophrys ?

E. T. Newton, Mem. Geol. Survey, Vert. Pliocene, 1891, pl. x., f. 1,
p. 88.
Red Crag. [7284] Woodbridge.

E. T. Newton, Mem. Geol. Survey, Vert. Pliocene, 1891, pl. x., figs. 2,
3, p. 88.
Red Crag. [1971] Boyton.

Chrysophrys ? ("Genus doubtful.")

E. T. Newton, Mem. Geol. Survey, Vert. Forest Bed, 1882, pl. xix.,
f. 12.
Weybourn Crag. [C.R. 981] East Runton.

Esox lucius, Linnæus.

E. T. Newton, Mem. Geol. Survey, Vert. Forest Bed, 1882, pl. xviii.,
figs. 11, 13, p. 123.
Forest Bed (U.F.B.) [C.R. 525, C.R. 536.] West Runton.

E. T. Newton, Mem. Geol. Survey, Vert. Forest Bed, 1882, pl. xviii., f. 14,
p. 123.
Forest Bed. [Blake 4] Kessingland

Fish scale.

E. T. Newton, Mem. Geol. Survey, Vert. Forest Bed, 1882, pl. xviii.,
f. 10.
Forest Bed. (King Coll.) [7351] Happisburgh.

Gadus elegans (Koken).

E. T. Newton, Mem. Geol. Survey, Vert. Pliocene, 1891, pl. x., f. 16,
p. 96.
Coralline Crag. [1007] Sutton.

Gadus luscus, Linnæus.

E. T. Newton, Mem. Geol. Survey, Vert. Pliocene, 1891, pl. x., f. 8, p. 94.
Red Crag. [1969] Boyton.

Gadus minutus? Linnæus.

E. T. Newton, Mem. Geol. Survey, Vert. Pliocene, 1891, pl. x.,
figs. 9, 10, 11, p. 95.
Coralline Crag. [7285] Sutton.

Gadus morrhua, Linnæus.

E. T. Newton, Mem. Geol. Survey, Vert. Forest Bed, 1882, pl. xix., f. 4,
p. 127.
Forest Bed. [C.R. 594] Trimingham.
E. T. Newton, Mem. Geol. Survey, Vert. Forest Bed, 1882, pl. xix.,
f. 5, p. 127.
Forest Bed. [C.R. 660] Mundesley.

Gadus pollachius? Linnæus.

E. T. Newton, Mem. Geol. Survey, Vert. Forest Bed, 1882, pl. xviii.,
f. 24, p. 128.
Weybourn Crag. [C.R. 880] East Runton.

Gadus pseudæglefinus? Newton.

E. T. Newton, Mem. Geol. Survey, Vert. Pliocene, 1891, pl. x., figs. 6 a,
b, 7, p. 94.
Coralline Crag. [2183, 7286] T. Gedgrave.

Gadus virens? Linnæus.

E. T. Newton, Mem. Geol. Survey, Vert. Pliocene, 1891, pl. x., figs. 13,
14, p. 96.
Coralline Crag. [1007] Sutton.

Galeus canis, Linnæus.

E. T. Newton, Mem. Geol. Survey, Vert. Forest Bed, 1882, pl. xix., f. 7,
p. 130.
Weybourn Crag. [C.R. 981] East Runton.
E. T. Newton, Mem. Geol. Survey, Vert. Pliocene, 1891, pl. ix., f. 9,
p. 102.
Pliocene. [7377] St. Erth.

Leuciscus erythrophthalmus, Linnæus.

E. T. Newton, Mem. Geol. Survey, Vert. Forest Bed, 1882, pl. xviii.,
f. 18, p. 126.
Forest Bed (U.F.B.). [C.R. 868] Mundesley.

Notidanus gigas, Sismonda.

E. T. Newton, Mem. Geol. Survey, Vert. Pliocene, 1891, pl. ix.,
f. 18, p. 108.
Red Crag. [7357] Butley Marshes, Boyton.

Odontaspis contortidens, Agassiz.

E. T. Newton, Mem. Geol. Survey, Vert. Pliocene, 1891, pl. ix.,
f. 17 *a, b*, p. 107.

Red Crag. [1978] Boyton.

Odontaspis (Lamna) elegans, Agassiz.

E. T. Newton, Mem. Geol. Survey, Vert. Pliocene, 1891, pl. ix.,
f. 16 *a, b*, p. 107.

Red Crag. [7293] Suffolk.

Otoliths, probably **gadoid**.

E. T. Newton, Mem. Geol. Survey, Vert. Forest Bed., 1882, pl. xviii.,
figs. 25, 26, p. 128.

Weybourn Crag. [C.R. 880] East Runton.

Oxyrhina hastalis, Agassiz.

E. T. Newton, Mem. Geol. Survey, Vert. Pliocene, 1891, pl. ix.,
f. 15 *a, b*, p. 106.

Red Crag. [2163] Suffolk.

Perca fluviatilis, Linnaeus.

E. T. Newton, Mem. Geol. Survey, Vert. Forest Bed, 1882, pl. xviii.,
f. 7, p. 120.

Forest Bed. [Blake 3] Kessingland.

E. T. Newton, Mem. Geol. Survey, Vert. Forest Bed, 1882, pl. xviii.,
f. 8, p. 120.

Forest Bed. (King Coll.) [7342] Happisburgh.

E. T. Newton, Mem. Geol. Survey, Vert. Forest Bed, 1882, pl. xviii.,
figs. 2-6, p. 120.

Forest Bed (U.F.B.). [C.R. 524, C.R. 523, C.R. 519] West Runton.

Platax Woodwardi, Agassiz.

E. T. Newton, Mem. Geol. Survey, Vert. Forest Bed, 1882, pl. xix., f. 1,
p. 122.

Forest Bed. (King Coll.) [7353] Norfolk?

E. T. Newton, Mem. Geol. Survey, Vert. Forest Bed, 1882, pl. xix.,
f. 3, p. 122.

Weybourn Crag. [C.R. 885] Trimingham.

Raja batis, Montagu.

E. T. Newton, Mem. Geol. Survey, Vert. Forest Bed, 1882, pl. xix., f. 9,
p. 131.

Weybourn Crag. [C. R. 981] East Runton.

Raja clavata, Linnaeus.

E. T. Newton, Mem. Geol. Survey, Vert. Forest Bed, 1882, pl. xix., figs.
10, 11, p. 132.

Weybourn Crag. [C.R. 981] East Runton.

E. T. Newton, Mem. Geol. Survey, Vert. Pliocene, 1891, pl. ix., figs. 19,
20, p. 111.

Red Crag. [7291, 7292] Boyton.

Raja *sp.*

E. T. Newton, Mem. Geol. Survey, Vert. Pliocene, 1891, pl. ix.,
f. 21 *a, b*, p. 112.

Coralline Crag. [3196] Gedgrave.

Tinca vulgaris, Cuvier.

E. T. Newton, Mem. Geol. Survey, Vert. Forest Bed, 1882, pl. xviii.,
f. 23, p. 127.

Forest Bed (U.F.B.) [C.R. 504, C.R. 508] West Runton.

AMPHIBIA, REPTILIA, AVES.

Bufo sp. (Ilium).

E. T. Newton, Mem. Geol. Survey, Vert. Forest Bed, 1882, pl. xvii.,
f. 8, p. 118.

Forest Bed (U.F.B.) [7340] West Runton.

Triton cristatus, Laur. (Femur).

E. T. Newton, Mem. Geol. Survey, Vert. Forest Bed, 1882, pl. xvii.,
figs. 9, 9 a, p. 119.

Forest Bed (U.F.B.) [7341] West Runton.

Pelias berus, Linnæus (Vertebra).

E. T. Newton, Mem. Geol. Survey, Vert. Forest Bed, 1882, p. xvii.,
figs. 6, 6 a, b, p. 115.

Forest Bed (U.F.B.) [C.R. 956] West Runton.

Diomedea sp. (Ulna).

E. T. Newton, Mem. Geol. Survey, Vert. Pliocene, 1891, pl. ix., f. 1,
p. 85.

Coralline Crag. [7283] Orford.

MAMMALIA.

Ailurus anglicus, Dawkins (Tooth).

E. T. Newton, Quart. Journ. Geol. Soc., vol. xlv., 1890, pl. xviii.,
f. 9, p. 451; Mem. Geol. Survey, Vert. Pliocene, 1891, pl. i., f. 18, p. 13.
p. 13.

Red Crag. [3924] near Boyton.

Antelope? (Cheek teeth).

E. T. Newton, Mem. Geol. Survey, Vert. Pliocene, 1891, pl. iii.,
figs. 2 a-c, 3 a-c, p. 23.

Red Crag. [3935] Woodbridge.

E. T. Newton, *Ibid.*, 1891, pl. iii., f. 4, p. 23.

Red Crag. [3922] Sutton.

E. T. Newton, *Ibid.*, 1891, pl. ii., f. 5, p. 23.

Red Crag. [3929] Boyton.

Arvicola arvalis, Pallas (Jaw and teeth).

E. T. Newton, Mem. Geol. Survey, Vert. Forest Bed, 1882, pl. xiv.,
figs. 2-5, p. 88.

Forest Bed. (U.F.B.) [C.R. 951] West Runton.

Arvicola arvalis, Pallas, var. (Cheek teeth).

E. T. Newton, Mem. Geol. Survey, Vert. Forest Bed, 1882, pl. xiv., f. 7,
p. 90.

Forest Bed. (U.F.B.) [C.R. 516] West Runton.

Arvicola (Evotomys) glareolus, Schreber (Jaw and teeth).

E. T. Newton, Mem. Geol. Survey, Vert. Forest Bed, 1882, pl. xiv.,
figs. 1, 1 a-c, p. 82.

Forest Bed (U.F.B.) [C.R. 955] West Runton.

Arvicola gregalis (Pallas) (Jaw and teeth).

E. T. Newton, Mem. Geol. Survey, Vert. Forest Bed, 1882, pl. xiv.,
figs. 6, 6 a, p. 90.

Forest Bed (U.F.B.) [C.R. 905] West Runton.

Arvicola (Evotomys) intermedius, Newton (Jaws and teeth). T.

E. T. Newton, Mem. Geol. Survey, Vert. Forest Bed, 1882, pl. xiii.,
figs. 2-7, p. 83.

Forest Bed (U.F.B.) [C.R. 906, C.R. 514] West Runton.

- Arvicola (Evotomys) intermedius**, Newton (Cheek tooth). T.
E. T. Newton, Mem. Geol. Survey, Vert. Forest Bed, 1882, pl. xiii.,
f. 8, p. 83.
Weybourn Crag. [C.R. 886] Trimingham.
- Arvicola (Evotomys) intermedius**, Newton (Humerus). T.
E. T. Newton, Mem. Geol. Survey, Vert. Forest Bed, 1882, pl. xiii.,
figs. 10, 10 a, p. 83.
Forest Bed. [7460] Kessingland.
- Arvicola sp.** (Humerus and ulna).
E. T. Newton, Mem. Geol. Survey, Vert. Forest Bed, 1882, pl. xiv., f. 9.
Forest Bed (Unio Bed). [C.R. 888] Sidestrand.
E. T. Newton, Mem. Geol. Survey, Vert. Forest Bed, 1882, pl. xiv., f. 10.
Forest Bed (U.F.B.). [C.R. 870] West Runton.
- Balæna affinis**, Owen (Tympanic).
E. T. Newton, Mem. Geol. Survey, Vert. Pliocene, 1891, pl. vi., f. 3,
p. 58.
Red Crag. [7294] Felixstow.
- Balæna (Balænotus) insignis** (Van Beneden) (Tympanic).
E. T. Newton, Mem. Geol. Survey, Vert. Pliocene, 1891, pl. vi., f. 4, p. 59.
Red Crag. [7295] Woodbridge.
- Balæna primigenia**, Van Beneden (Tympanic).
E. T. Newton, Mem. Geol. Survey, Vert. Pliocene, 1891, pl. vi., f. 2 a, b,
p. 58.
Red Crag. [7356] Woodbridge.
- Balæna primigenia**, Van Beneden var. B., Lydekker (Tympanic). T.
R. Lydekker, Quart. Journ. Geol. Soc., vol. xliii., 1887, pl. ii., figs. 1,
1 a, p. 7.
Red Crag. [7355] Woodbridge.
- Balænodon physaloides**, Owen (Teeth).
E. T. Newton, Mem. Geol. Survey, Vert. Pliocene, 1891, pl. vii.,
f. 2 a, b, p. 66.
Red Crag. [3044] Suffolk.
E. T. Newton, Mem. Geol. Survey, Vert. Pliocene, 1891, pl. vii.,
f. 3 a, b, p. 66.
Red Crag. [3931] Woodbridge.
- Balænoptera definita** (Owen) (Tympanic).
E. T. Newton, Mem. Geol. Survey, Vert. Pliocene, 1891, pl. vi., f. 8, p. 61.
Red Crag. [7296] Felixstow.
- Balænoptera emarginata** (Owen) (Tympanic).
E. T. Newton, Mem. Geol. Survey, Vert. Pliocene, 1891, pl. vi.,
f. 9 a, b, p. 62.
Red Crag. [2352] Felixstow.
- Belemnoziphius compressus**, Huxley (Rostrum). T.
T. H. Huxley, Quart. Journ. Geol. Soc., vol. xx., 1864, pl. xix., figs
A-D, p. 393.
Red Crag. [7278] Blackheath, three miles east of Ipswich.
- Bovine** (Lower molar).
E. T. Newton, Mem. Geol. Survey, Vert. Pliocene, 1891, pl. iii., f. 1, p. 21
Red Crag. [2000] Boyton.

Canis lupus, Linnæus (Humerus).

E. T. Newton, Mem. Geol. Survey, Vert. Forest Bed, 1882, pl. iv., figs. 1, 1 *a*, p. 19.
Forest Bed? (King Coll.) [7329] Norfolk?

Capreolus caprea? Gray (Antler).

E. T. Newton, Mem. Geol. Survey, Vert. Pliocene, 1891, pl. iv., f. 10, p. 33.
Forest Bed. (King Coll.) [7324] Happisburgh.

Castor europæus, Owen (Jaw).

E. T. Newton, Mem. Geol. Survey, Vert. Forest Bed, 1882, pl. xii., figs. 1-3, p. 78.
Forest Bed (U.F.B.). [C.R. 894] West Runton.

Castor europæus, Owen (pm_T).

E. T. Newton, Mem. Geol. Survey, Vert. Forest Bed, 1882, pl. xii., f. 8, p. 78.
Forest Bed. (King Coll.) [7344] Norfolk?

Castor europæus, Owen. (Tibia).

E. T. Newton, Mem. Geol. Survey, Vert. Forest Bed, 1882, pl. xii., f. 9, p. 78.
Forest Bed (U.F.B.). [C. R. 890] West Runton.

Castor fiber, Linnæus (pm_T).

E. T. Newton, Mem. Geol. Survey, Vert. Pliocene, 1891, pl. v., f. 16 *a*, *b*, p. 49.
Red Crag. [3925] Boyton.

Cervus ardeus, Croizet and Jobert (Antler)

E. T. Newton, Mem. Geol. Survey, Vert. Pliocene, 1891, pl. iv., f. 6, p. 25.
Norwich Crag. (King Coll.) [92] Thorpe, Norwich.

Cervus carnutorum, Laugel (Antler).

E. T. Newton, Mem. Geol. Survey, Vert. Pliocene, 1891, pl. iv., f. 3, p. 26.
Norwich Crag. [7322] Covehithe, Suffolk.

Cervus Dawkinsi, Newton. *Vide C. verticornis*.**Cervus etueriarum**, (Croizet and Jobert) (Antler).

E. T. Newton, Mem. Geol. Survey, Vert. Pliocene, 1891, pl. iv., f. 5, p. 27.
Forest Bed. (King Coll.) [7323] Cromer.

Cervus tetraceros, Mackie (Antler).

E. T. Newton, Mem. Geol. Survey, Vert. Pliocene, 1891, pl. iv., f. 2, p. 32.
Forest Bed. [C.R. 973] East Runton.

Cervus verticornis, Dawkins (Antler).

W. Boyd Dawkins, Mon. Pal. Soc., 1887, pl. v., f. 2, p. 22; C. Reid, Mem. Geol. Survey, Pliocene, 1890, p. 183 (text figure 45).
Forest Bed. [7368] Kessingland, Suffolk.

Cervus verticornis, Dawkins (Antler).

W. Boyd Dawkins, Quart. Journ. Geol. Soc., vol. xxviii., 1872, p. 407 (text figure). Described as **Cervus Dawkinsi**, E. T. Newton, Mem. Geol. Survey, Vert. Forest Bed, 1882, p. 54. Refigured, W. Boyd Dawkins, Mon. Pal. Soc., 1887, pl. ii., f. 1, p. 7.
Forest Bed. (King Coll.) [7321] Norfolk?

Cervus sp., (Cheek teeth.)

E. T. Newton, Mem. Geol. Survey, Vert. Pliocene, 1891, pl. iii., figs. 8 *a*, *b*, 9 *a*, *b*, p. 25.
Red Crag. [7309, 7310] Woodbridge and Boyton.

Cetotherium (Plesiocetus) dubium (v. Beneden) (Tympanic).

E. T. Newton, Mem. Geol. Survey, Vert. Pliocene, 1891, pl. vi., f. 10 *a*,
b, p. 63.
 Red Crag. [7316] Felixstow.

Choneziphius planirostris (Cuvier) (Periotic).

R. Lydeker, Quart. Journ. Geol. Soc., vol. xliii., 1887, pl. ii., f. 7,
 p. 14; E. T. Newton, Mem. Geol. Survey, Vert. Pliocene, 1891, pl. viii.,
 f. 6, p. 69.
 Red Crag. [7298] Woodbridge.

Coryphodon (Cheek tooth).

E. T. Newton, Mem. Geol. Survey, Vert. Pliocene, 1891, pl. v.,
 f. 12 *a*, *b*, p. 41.
 Red Crag. [7287] Woodbridge.

Delphinus (Phocæna) orcoides, Lankester (Tooth).

E. Ray Lankester, Ann. Mag. Nat. Hist., Ser. 3, vol. xiv., 1864, pl. viii.,
 figs. 17, 18, p. 356.
 Red Crag. [7305] Woodbridge.

Delphinoid ? (Periotic).

E. T. Newton, Mem. Geol. Survey, Vert. Pliocene, 1891, pl. viii., f. 9, p. 80.
 Red Crag. [7299] Woodbridge.

Delphinoid. (Periotics).

E. T. Newton, Mem. Geol. Survey, Vert. Pliocene, 1891, pl. viii., figs.
 10 *a*, *b*, 11 *a*, *b*, 12 *a*, *b*, p. 80.
 Red Crag. Figs. 10, Felixstow, 7302; 11, Woodbridge, 7303;
 12, Boyton, 7304.

Delphinoid (Right tympanic).

E. T. Newton, Mem. Geol. Survey, Vert. Pliocene, 1891, pl. viii., f. 13,
 p. 80.
 Red Crag. [7312] Boyton.

Elephas meridionalis, Nesti (m 3).

A. Leith Adams, Mon. Pal. Soc., 1881, pl. xviii., f. 4, p. 196.
 Forest Bed. (King Coll.) [7333] Mundesley.

A. Leith Adams, Mon. Pal. Soc., 1881, pl. xvii., f. 8. (last milk molar).
 Forest Bed. (King Coll.) [7332] Cromer.

Equus caballus-fossilis, Rüttimeyer (m²).

E. T. Newton, Mem. Geol. Survey, Vert. Forest Bed, 1882, pl. vii., figs.
 8, 8 *a*, p. 30.
 Forest Bed. (King Coll.) [7330] Cromer.

Equus stenonis, Cocchi (m¹ ?).

E. T. Newton, Mem. Geol. Survey, Vert. Forest Bed, 1882, pl. vii.,
 figs. 10, 10 *a*, p. 35.
 Forest Bed. (King Coll.) [7331] Cromer.

Equus stenonis, Cocchi (Cheek tooth).

E. T. Newton, Mem. Geol. Survey, Vert. Pliocene, 1891, pl. v., f. 7 *a*, *b*,
 p. 37.
 Norwich Crag. [7314] Thorpe, Norwich.

Eucetus amblyodon, Du Bus (Teeth).

E. T. Newton, Mem. Geol. Survey, Vert. Pliocene, 1891, pl. viii., figs.
 1, 2, p. 65.
 Red Crag. [7317, 7318] Woodbridge.

Felis ? (Fibula).

E. T. Newton, Mem. Geol. Survey, Vert. Forest Bed, 1882, pl. iv., figs. 4, 4 a, p. 23.

Forest Bed. (King Coll.) [7327] Norfolk ?

Gazella anglica, Newton (Frontal and horn-core). **T.**

E. T. Newton, Quart. Journ. Geol. Soc., vol. xl., 1884, pl. xiv., figs. 1, 2, 3, 6, p. 280 ; Mem. Geol. Survey, Vert. Pliocene, 1891, pl. iii., f. 6 a-c, p. 23.

Norwich Crag. [7325, 89] Thorpe.

Globicephalus uncidens (Lankester) (Periotic).

E. T. Newton, Mem. Geol. Survey, Vert. Pliocene, 1891, pl. viii., f. 8, p. 77. (See also *Delphinus orcoides*.)

Red Crag. [7301] Woodbridge.

Herpetocetus scaldiensis, v. Beneden (Tympanic).

E. T. Newton, Mem. Geol. Survey, Vert. Pliocene, 1891, pl. vi., f. 11 a, b, p. 64.

Red Crag. [7315] Felixstow.

Hipparion gracile (Kaup) (Cheek teeth).

E. T. Newton, Mem. Geol. Survey, Vert. Pliocene, 1891, pl. v., f. 8 a, b, p. 37.

Red Crag. [7313] Woodbridge.

E. T. Newton, Mem. Geol. Survey, Vert. Pliocene, 1891, pl. v., f. 9 a, b, p. 37.

Red Crag. (Baker Coll.) [7307, 7308] Woodbridge.

Hyracotherium leporinum, Owen (Cheek teeth).

E. T. Newton, Mem. Geol. Survey, Vert. Pliocene, 1891, pl. v., f. 6, p. 41.

Red Crag. [1091] Boyton.

Martes sylvatica, Nilsson (m_I).

E. T. Newton, Mem. Geol. Survey, Vert. Forest Bed, 1882, pl. iv., figs. 3, 3 a, p. 25.

Forest Bed (U.F.B.) [C.R. 501] West Runton.

Mastodon arvernensis, Croizet and Jobert (pm_T).

C. Reid, Mem. Geol. Survey, Pliocene, 1890, p. 15 (text figure).

Red Crag. [1983] Boyton.

Megaptera affinis (v. Beneden) (Tympanic).

R. Lydekker, Quart. Journ. Geol. Soc., vol. xliii., 1887, pl. ii., figs. 4, 4 a, p. 7 ; E. T. Newton, Mem. Geol. Survey, Vert. Pliocene, 1891, pl. vi., f. 6 a, b, p. 60.

Coralline Crag. [7279] Sudbourn, Suffolk.

Mesoplodon longirostris ? (Cuvier) (Periotic).

R. Lydekker, Quart. Journ. Geol. Soc., vol. xliii., 1887, pl. ii., f. 8, p. 7 ;

E. T. Newton, Mem. Geol. Survey, Vert. Pliocene, 1891, pl. viii., f. 7, p. 72.

Red Crag. [7297] Woodbridge.

Mesoplodon scaphoides, Newton (Rostrum). **T.**

E. T. Newton, Quart. Journ. Geol. Soc., vol. xlvi., 1890, pl. xviii., f. 8 a, b, p. 450.

Red Crag. [7277] Near Woodbridge.

Mus sylvaticus, Linnæus (Jaw with teeth).

E. T. Newton, Mem. Geol. Survey, Vert. Forest Bed, 1882, pl. xiv., figs. 11, 11 a, p. 93.

Forest Bed (U.F.B.) [C.R. 899] West Runton.

Myogale moschata (Linnæus) (Vertebra).

E. T. Newton, Mem. Geol. Survey, Vert. Forest Bed, 1882, pl. xvi., figs. 4, 4 a, b, p. 98.

Forest Bed (U.F.B.).

[C.R. 909] West Runton.

Orca citoniensis, Capellini (Periotic).

R. Lydekker, Quart. Journ. Geol. Soc., vol. xliii, 1887, pl. ii., f. 9, p. 7 ;
E. T. Newton, Mem. Geol. Survey, Vert. Pliocene, 1891, pl. viii., f. 5,
p. 76.

Red Crag.

[7300] Woodbridge.

Phoca (Radius).

E. T. Newton, Mem. Geol. Survey, Vert. Forest Bed, 1882, pl. v., figs. 1, 1 a, b, p. 29.

Forest Bed.

[C.R. 875] Wood Hill, Runton.

Physeter macrocephalus, Linnæus (Tooth).

E. T. Newton, Quart. Journ. Geol. Soc., vol. xlii., 1886, pl. xi., figs. 1-4,
p. 316 ; E. T. Newton, Mem. Geol. Survey, Vert. Pliocene, 1891,
pl. vii., f. 1, p. 65.

Forest Bed.

[1500] Sidestrand.

Rhinoceros etruscus, Falconer (pm⁴).

E. T. Newton, Mem. Geol. Survey, Vert. Forest Bed, 1882, pl. viii.,
figs. 6, 6 a, p. 38.

Forest Bed.

[7335] Pakefield.

Rhinoceros incisivus (Kaup) (up. pm.).

E. T. Newton, Mem. Geol. Survey, Vert. Pliocene, 1891, pl. v., f. 1 a, b,
p. 38.

Red Crag.

[7289] Woodbridge.

Ruminant, genus ? (Metatarsus).

E. T. Newton, Mem. Geol. Survey, Vert. Pliocene, 1891, pl. iii., figs. 7,
7 a, b, p. 24.

Coralline Crag.

[7281, 7282] Gedgrave.

Sorex pygmæus? Pallas (Jaw and teeth).

E. T. Newton, Mem. Geol. Survey, Vert. Forest Bed, 1882, pl. xv., figs. 11, 12, p. 97.

Forest Bed (U.F.B.).

[C.R. 953] West Runton.

Sorex vulgaris, Linnæus (Jaws, teeth, humerus, and femur).

E. T. Newton, Mem. Geol. Survey, Vert. Forest Bed, 1882, pl. xv., figs. 5-10 a, p. 97.

Forest Bed (U.F.B.).

[C.R. 537, C.R. 900, C.R. 53] West Runton.

Sus palæochærus, Kaup (m $\frac{3}{5}$).

E. T. Newton, Mem. Geol. Survey, Vert. Pliocene, 1891, pl. iii., f. 13,
p. 36.

Red Crag.

[7306] Boyton.

E. T. Newton, Mem. Geol. Survey, Vert. Pliocene, 1891, pl. iii., f. 14,
p. 36.

Red Crag.

[7311] Woodbridge.

Sus scrofa? Linnæus (m $\frac{5}{5}$).

E. T. Newton, Mem. Geol. Survey, Vert. Forest Bed, 1882, pl. ix., f. 3,
p. 43.

Forest Bed ?

(King Coll.)

[7354] Norfolk ?

Tapirus arvernensis, Devèze and Bouillet (Cheek teeth).

E. T. Newton, Mem. Geol. Survey, Vert. Pliocene, 1891, pl. v., f. 10 a, b,
p. 40.
Red Crag. [7288] Woodbridge.

E. T. Newton, Mem. Geol. Survey, Vert. Pliocene, 1891, pl. v., f. 11 a, b,
p. 40.
Red Crag. [7290] Boyton.

Trogontherium Cuvieri, Owen. (Maxilla with teeth).

R. Owen, Geol. Magazine, vol. vi., 1869, f. 1, p. 49 (text figure) ; E. T.
Newton, Mem. Geol. Survey, Vert. Forest Bed, 1882, pl. xi., f. 13,
p. 65.
Forest Bed. (King Coll.) [7343] Norfolk †

Trogontherium Cuvieri, Owen (pm $\frac{1}{4}$; m $\frac{1}{1}$, $\frac{2}{2}$, $\frac{3}{3}$).

E. T. Newton, Mem. Geol. Survey, Vert. Forest Bed, 1882, pl. xi., f. 8,
p. 65.
Forest Bed. [C.R. 492] East of Cromer.

Trogontherium Cuvieri, Owen (pm $\frac{1}{4}$; m $\frac{1}{1}$, $\frac{2}{2}$).

R. Owen, Geol. Magazine, vol. vi., 1869, f. 3, p. 51 (text-figure) ;
E. T. Newton, Mem. Geol. Survey, Vert. Forest Bed, 1882, pl. xi.,
f. 10, p. 65.
Forest Bed. (King Coll.) [7342] Mundesley.

Trogontherium Cuvieri, Owen (Tibia and fibula).

R. Owen, Geol. Magazine, vol. vi., 1869, pl. iii., figs. 4-7, p. 55 ;
E. T. Newton, Mem. Geol. Survey, Vert. Forest Bed, 1882, pl. xi.
figs. 19, 19 a, p. 65.
Forest Bed. (King Coll.) [7345] Mundesley.

Tursiops (Delphinus) tursio ? (Bonnaterre) (Vertebra).

E. T. Newton, Mem. Geol. Survey, Vert. Pliocene, 1891, pl. viii.,
f. 14 a, b, p. 80.
Coralline Crag. [C.R. 280] Broom Pit, Gedgrave.

Ursus ferox-fossilis ? Busk (Max. and teeth).

E. T. Newton, Mem. Geol. Survey, Vert. Forest Bed, 1882, pl. i.,
figs. 5, 5 a, p. 11.
Forest Bed. (King Coll.) [7328] Mundesley †

Ursus spelæus, Blumenbach (pm $\frac{1}{4}$, m $\frac{2}{2}$).

E. T. Newton, Mem. Geol. Survey, Vert. Forest Bed, 1882, pl. ii.,
figs. 2, 3, p. 11.
Forest Bed. [7337, 7338] Overstrand, Cromer.

PLEISTOCENE.

PLANTÆ.

Salix repens? Linnæus.

Oswald Heer, Phil. Trans., vol. 152, 1863, pl. lxxi., f. 6, p. 1081.

Pleistocene. [7367] Bovey Tracey, Devon.

Salix cinerea, Linnæus ; **Salix repens**, Linn. ? ; **Betula nana**, Linn.

Oswald Heer, Phil. Trans., vol. 152, 1863, pl. lxxi., f. 1 a-k, p. 1080.

Pleistocene. [7360] Bovey Tracey, Devon.

ANIMALIA.

GASTEROPODA.

Fusus longiroster, Brocchi.G. W. Lamplugh, Mem. Geol. Survey, I. of Man. (*In the press*).

Pleistocene. [7364] Cranstall Pt., I. of Man.

Fusus nov. sp.? Forbes.

T.

Ed. Forbes, "Malacologia monensis," Cat. Mollusca I. of Man (Edin.), 1838, pl. iii., f. 1, p. 60 ; G. W. Lamplugh, Mem. Geol. Survey, I. of Man.

Pleistocene. [7363] North Coast of Isle of Man
(washed on shore).**Nassa Kermodei**, Kendal.

G. W. Lamplugh, Mem. Geol. Survey, I. of Man.

Pleistocene. [6163] Cranstall Pt., I. of Man.

Nassa monensis, Forbes.

G. W. Lamplugh, Mem. Geol. Survey, I. of Man.

Pleistocene. [6165] Cranstall Pt., I. of Man.

Trophon clathratus, Linnæus.

G. W. Lamplugh, Mem. Geol. Survey, I. of Man.

Pleistocene. [6673] Cranstall Pt., I. of Man.

AVES.

Colymbus septentrionalis, Linnæus (Bones).

E. T. Newton, Geol. Mag., 1883, pl. iii., figs. 1-7 a, p. 97.

Pleistocene (Mundesley River Bed). [108] Mundesley.

MAMMALIA.

Elephas antiquus, Falconer (p.m.²).Leith Adams, Mon. Pal. Soc., 1879, pl. xii., figs. 3, 3 a, p. 86. (Humerus),
Mon. Pal. Soc., 1879, pl. xvi., figs. 6, p. 214, 233.

Pleistocene. (Cotton Coll.) [7369, 7371] Ilford, Essex.

Elephas primigenius, Blumenbach (m.²).

Leith Adams, Mon. Pal. Soc., 1879, pl. xii., f. 1, p. 106.

Pleistocene. [7373] Crayford.

- Microtus (Arvicola) ratticeps** (Key. and Blasius) (Cheek teeth).
 E. T. Newton, Geol. Mag., 1890, p. 454, f. 1.
 Pleistocene. [3085] Crayford.
 E. T. Newton, Geol. Mag., 1890, p. 454, f. 2.
 Pleistocene. [5643] Erith.
- Mustela robusta**, Newton (Skull and lower jaw). T.
 E. T. Newton, Quart. Journ. Geol. Soc., vol. lv., 1899, pl. xxviii.,
 figs. 1-3, p. 425.
 Pleistocene. [6630] Ightham Fissure, Kent.
- Myodes lemmus** (Linnæus) (Cheek teeth).
 E. T. Newton, Geol. Mag., 1890, p. 454, figs. 7, 8.
 Pleistocene. (Spurrell Coll.) [5640] Erith.
- Myodes torquatus** (Desmarest) (Cheek teeth).
 E. T. Newton, Geol. Mag., 1890, p. 454, figs. 3-6.
 Pleistocene. (Spurrell Coll.) [5641] Erith.
- Spermophilus altaicus**, Eversmann (Teeth and bones).
 E. T. Newton, Geol. Mag., 1882, pl. ii., figs. 1-13, p. 51.
 Pleistocene (Arctic Fresh-water Bed). [6370] Mundesley.
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APPENDIX B.

CATALOGUE of TYPES and FIGURED SPECIMENS from BRITISH
DEVONIAN STRATA preserved in the MUSEUM of PRACTICAL
GEOLOGY, London.

By H. A. ALLEN, F.G.S.

Each specimen is entered under the name given to it when first figured. When the author's name is placed in brackets, (Phillips), it refers only to the species and not to the genus. The letter **T** indicates that the specimen is the type of the species. The identity of some few specimens is not quite certain: these are marked [**Doubtful**]. The figures in square brackets, [7009], correspond to the number in the Museum Register.

The following abbreviations are employed:—

Trans. Geol. Soc.: Transactions of the Geological Society of London.

Quart. Journ. Geol. Soc.: Quarterly Journal of the Geological Society of London.

Mon. Pal. Soc.: Monograph of the Palæontographical Society London.

Pal. Foss.: Figures and Descriptions of the Palæozoic Fossils of Cornwall, Devon, and West Somerset, by John Phillips, 1841.

ANIMALIA.

CÆLENTERATA.

Sphæronites tessellatus, Phillips.

T.

H. T. de la Beche, Trans. Geol. Soc., Ser. 2, vol. iii., 1832, pl. xx., f. 1, p. 164 ("An undescribed fossil"). Refigured J. Phillips, Pal. Foss., pl. lix., f. 49**, p. 135. Refigured as **Sphærospongia tessellata**, G. J. Hinde, Quart. Journ. Geol. Soc., xl., 1884, pl. xxxvii., f. 1, *b c*, p. 135.

Middle Devonian. [7222, 7223] St. Mary Church, Torquay.

Sphærospongia tessellata. *Vide Sphæronites*.

Calceola sandalina (Linnaeus).

J. Phillips, Pal. Foss., pl. lx., f. 102*, p. 137; Davidson, Mon. Pal. Soc., 1865, pl. xx., f. 13, p. 105.

Middle Devonian. [7086] Chircombe Bridge, Newton.

Pleurodictyum problematicum, Goldfuss.

J. Phillips, Pal. Foss., pl. ix., f. 24 *a—c*, p. 19.

Lower Devonian. [6875] Meadfoot, Torquay.

J. Phillips, Pal. Foss., pl. lx., f. 24 *a, b*, p. 230.

Middle Devonian. [6934] Ogwell, Newton.

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Strombodes helianthoides, Goldfuss.

J. Phillips, Pal. Foss., pl. v., f. 13 *a*, p. 10.
Middle Devonian. [7084] Mudstone Bay, Devonshire.

Turbinolopsis bina, Lonsdale.

J. Phillips, Pal. Foss., pl. i., f. 2 *b*, *c*, p. 4.
Upper Devonian (Pilton Beds). [7170] Combe, Ashburton, Devon.

Turbinolopsis pluriradialis, var. *α*, Phillips.

J. Phillips, Pal. Foss., pl. ii., f. 5 *a*, *b*, *d*, p. 5.
Upper Devonian (Pilton Beds). [7171] Brushford, N. Devon.

ECHINODERMATA.

Actinocrinus ? Batheri, Whidborne.

T.

G. F. Whidborne, Mon. Pal. Soc., 1898, pl. xxxii., figs. 2, 2 *a*, *b*, 3, 3 *a*, *b*,
p. 222.
Upper Devonian (Marwood Beds). [7145, 7146] Braunton.

Actinocrinus Porteri, Whidborne.

T.

G. F. Whidborne, Mon. Pal. Soc., 1898, pl. xxxi., figs. 1, 1 *a*, 2, 5 ;
pl. xxxii., f. 1, p. 220.
Upper Devonian. [7138-7141] North Devon.

Adelocrinus hystrix, Phillips.

T.

J. Phillips, Pal. Foss., pl. xvi., f. 42 *a*, *b*, p. 30 ; G. F. Whidborne
Mon. Pal. Soc., 1898, pl. xxx., f. 4, p. 224.
Upper Devonian (Pilton Beds). [7157] Brushford.

G. F. Whidborne, Mon. Pal. Soc., 1898, pl. xxx., figs. 7, 7 *a*, p. 224
Upper Devonian (Pilton, Beds.) [7156] Braunton, N. Devon.

Cupressocrinus crassus, Goldfuss.

G. F. Whidborne, Mon. Pal. Soc., 1895, pl. xxiv., figs. 4, 4 *a*, p. 207.
Middle Devonian. [7087] Newton Bushel.

Cyathocrinus ? ellipticus, Phillips.

T.

J. Phillips, Pal. Foss., pl. xvi., f. 49 *a—d*, p. 32.
Upper Devonian. [7147] Petherwin, Cornwall.

Cyathocrinus ? macrodactylus, Phillips,

J. Phillips, Pal. Foss., pl. xv., f. 41 *e*, p. 29. Refigured as **Taxocrinus
macrodactylus** : G. F. Whidborne, Mon. Pal. Soc., 1898, pl. xxxiii.,
f. 2, p. 215.

Upper Devonian (Pilton Beds). [7148] Pilton, North Devon.

Eugaster ? perarmatus (Whidborne).

T.

G. F. Whidborne, Mon. Pal. Soc., 1898, pl. xxvii., figs. 6, 6 *a*, p. 209.
Upper Devonian (Pilton Beds). [7163] Braunton Down.

Hexacrinus depressus, Austin.

T.

T. Austin, "Recent and Fossil Crinoidea," 1843, pl. vi., f. 2 *a—e*, p. 40.
Middle Devonian. [7089, 7091] Newton Bushel.

Hexacrinus interscapularis (Phillips).

G. F. Whidborne, Mon. Pal. Soc., 1895, pl. xxi., f. 2 ; pl. xxii., figs. 2,
2 *a*, p. 190. (See also *Platycrinus interscapularis*.)
Middle Devonian. [1549, 7090] Bradley and Newton Abbot.

Hexacrinus macrotatus, Austin.

T.

T. Austin, "Rec. and Foss. Crinoidea," 1843, pl. vi., figs. 3 *a*, *d*, p. 50.
G. F. Whidborne, Mon. Pal. Soc., 1895, pl. xxii., f. 6, p. 192. (See
also *Platycrinus tuberculatus* ?)
Middle Devonian. [6880] Newton Bushel.

Hexacrinus melo. *Vide* **Platycrinus interscapularis.****Hexacrinus ? pentangularis**, Austin.

T.

T. Austin, "Rec. and Foss. Crinoidea," 1843, pl. vii., figs. 1 *a-c*, p. 51.Refigured as **Hexacrinus quintangulus**, G. F. Whidborne, Mon.Pal. Soc. 1895, pl. xxiii., figs. 6, 6 *a, b*, p. 198.

Middle Devonian.

[7095]

Newton Bushel.

Hexacrinus perarmatus, Whidborne.

T.

G. F. Whidborne, Mon. Pal. Soc., 1895, pl. xxii., f. 10, p. 194.

Middle Devonian.

[6879]

Newton Bushel.

Hexacrinus quintangulus. *Vide* **Hexacrinus ? pentangularis.****Hexacrinus Vicarii**, Whidborne.

T.

G. F. Whidborne, Mon. Pal. Soc., 1895, pl. xxiii., f. 4, p. 197. (See

also *Platycrinus pentangularis* ?

Middle Devonian.

[7093]

Newton Bushel.

Lepidesthes ? devonians (Whidborne).

T.

G. F. Whidborne, Mon. Pal. Soc., 1898, pl. xxiv., figs. 1, 2 ; pl. xxv., f. 3 *a-f*, p. 200.

Upper Devonian (Pilton Beds).

[7160, 7161]

East of Barnstaple.

Ophiurella ? gregaria (Whidborne).

T.

G. F. Whidborne, Mon. Pal. Soc., 1898, pl. xxviii., f. 3, p. 210.

Upper Devonian (Pilton Beds).

[7162]

Braunton Down, N. Devon.

Palæaster longimanus, Whidborne.

T.

G. F. Whidborne, Mon. Pal. Soc., 1898, pl. xxvi., figs. 1, 1*a*, 2, 3, 3*a, b*, p. 204.

Upper Devonian (Pilton Beds).

[7162-7164]

Park near Braunton, and Baggy Point, North Devon.

Platycrinus interscapularis, Phillips.

T.

J. Phillips, Pal. Foss., pl. xiv., f. 39, *a-d*, p. 28. Refigured as **Hexacrinus melo**, Austin, "Rec. and Foss. Crinoidea," 1843, pl. vi., f. 1 *a-e*, p. 48 ; and as **Hexacrinus interscapularis**, G. F. Whidborne, Mon. Pal. Soc., 1895, pl. xxi., f. 1, 1 *a-d*, p. 190.

Middle Devonian.

[7088]

Newton Bushel.

Platycrinus pentangularis ? Phillips.

[Doubtful] T.

J. Phillips, Pal. Foss., pl. lx., f. 29**, p. 135. Refigured as **Hexacrinus Vicarii**, G. F. Whidborne, Mon. Pal. Soc., 1895, pl. xxiii., f. 5, p. 197.

Middle Devonian.

[7092]

Newton Bushel.

Platycrinus tuberculatus ?, Phillips.J. Phillips, Pal. Foss., pl. lx., f. 39, * p. 134. Refigured as **Hexacrinus macrotatus**, T., Austin, "Rec. and Foss. Crinoidea," 1843, pl. vi., f. 3 *b*, p. 50 ; Whidborne, Mon. Pal. Soc., 1895, pl. xxii., f. 8, p. 192.

Middle Devonian.

[7094]

Newton Bushel.

Poteriocrinus sp.

G. F. Whidborne, Mon. Pal. Soc., 1898, pl. xxxv., f. 4, p. 228.

Upper Devonian (Marwood Beds).

[7155]

Braunton Down, N. Devon.

Poteriocrinus sp.G. F. Whidborne, Mon. Pal. Soc., 1898, pl. xxxvi., figs. 9, 9 *a*, p. 228

Upper Devonian (Marwood Beds).

[7154]

Braunton Down, N. Devon.

- Protaster granifer** (Whidborne). T.
 G. F. Whidborne, Mon. Pal. Soc., 1898, pl. xxvi., figs. 5, 6, p. 207.
 Upper Devonian (Pilton Beds). [7165, 7166] North Devon.
- Protaster ? (Drepanaster) scabrosus**, Whidborne var. T.
 G. F. Whidborne, Mon. Pal. Soc., 1898, pl. xxviii., figs. 1, 2, p. 208.
 Upper Devonian. [7167, 7168] Croyde, N. Devon.
 G. F. Whidborne, Mon. Pal. Soc., 1898, pl. xxix., figs. 2, 2 a, p. 208.
 Upper Devonian (Pilton Beds). [7169] Braunton Down.
- Protocidaris acuaria** (Whidborne). T.
 G. F. Whidborne, Mon. Pal. Soc., 1898, pl. xxv., figs. 1, 2, p. 203.
 Upper Devonian (Pilton Beds). [7158, 7159] East of Barnstaple.
- Rhodocrinus (Acanthocrinus) sp.**
 G. F. Whidborne, Mon. Pal. Soc., 1895, pl. xxiv., figs. 6, 6 a, p. 204.
 Middle Devonian. [7096] Newton Bushel.
- Rhodocrinus ?**
 G. F. Whidborne, Mon. Pal. Soc., 1898, pl. xxxi., f. 3 a-d, p. 217.
 Upper Devonian (Marwood Beds). [7142, 7143] North Devon.
- Scaphiocrinus ? inordinatus ?** Whidborne.
 G. F. Whidborne, Mon. Pal. Soc., 1898, pl. xxxiv., f. 7, p. 230.
 Upper Devonian (Marwood Beds). [7151] Braunton, North Devon.
- Scaphiocrinus ? plumifer**, Whidborne. T.
 G. F. Whidborne, Mon. Pal. Soc., 1898, pl. xxxvi., figs. 1, 1 a, p. 228.
 Upper Devonian (Marwood Beds). [7153] Braunton, North Devon.
- Scaphiocrinus sp.**
 G. F. Whidborne, Mon. Pal. Soc., 1898, pl. xxxiv., figs. 8, 8 a, p. 231.
 Upper Devonian (Marwood Beds). [7152] Braunton, North Devon.
- Sphaerocrinus geometricus**, Goldfuss.
 G. F. Whidborne, Mon. Pal. Soc., 1895, pl. xxiv., f. 8, p. 211.
 Middle Devonian. [6878] Newton Bushel.
- Taxocrinus macrodactylus** Phillips).
 G. F. Whidborne, Mon. Pal. Soc., 1898, pl. xxxiii., figs. 3, 3 a, 4, 4 a, p. 215.
 (See also *Cyathocrinus ?*)
 Upper Devonian (Marwood Beds). [7149, 7150] North Devon.

CRUSTACEA.

- Brontes flabellifer**, Goldfuss.
 J. Phillips, Pal. Foss., pl. lvii., f. 254 a, p. 131.
 Middle Devonian. [6985] Newton Bushel.
- Calymene Latreillii**, Steininger.
 J. Phillips, Pal. Foss., pl. lvi., f. 249 a, b, p. 129.
 Upper Devonian. [7054, 7055] New Road Qy., Pilton, Barnstaple.
- Dechenella setosa** (Whidborne). T.
 G. F. Whidborne, Mon. Pal. Soc., 1899, pl. ii., figs. 16, 16 a, p. 27.
 Middle Devonian. [6987] Newton Bushel.
- Homalonotus Herschelii ?**, Murchison.
 J. Phillips, Pal. Foss., pl. lvii., f. 253 a-c, p. 130.
 Lower Devonian. [6872, 6873, 6874] Meadfoot Sands, Torquay.

Phacops cryptophthalmus, Emmerich.

J. W. Salter, Mon. Pal. Soc., 1864, pl. i., f. 8, p. 17. Refigured as **Phacops latifrons** (Bronn): G. F. Whidborne, Mon. Pal. Soc., 1889, pl. i. figs. 8, 8a, p. 7.

Middle Devonian. [6986] Newton Bushel, Devon.

Phacops granulatus (Muenster).

[Doubtful.]

J. W. Salter, Mon. Pal. Soc., 1864, pl. i., figs. 2, 3, 4, p. 18.

Upper Devonian. [7059, 7060] South Petherwin.

Phacops latifrons (Bronn).

J. W. Salter, Mon. Pal. Soc., 1864, pl. i., f. 9, p. 18.

Upper Devonian (Marwood Beds). [7057] North Devon.

J. W. Salter, Mon. Pal. Soc., 1864, pl. i., f. 10, p. 18.

Upper Devonian. [7053] Croyde.

J. W. Salter, Mon. Pal. Soc., 1864, pl. i., f. 14, p. 18; G. F. Whidborne, Mon. Pal. Soc., 1896, pl. i., f. 10, p. 10.

Upper Devonian. [7056] Baggy Point, North Devon.

G. F. Whidborne, Mon. Pal. Soc., 1896, pl. ii., f. 3, p. 11.

Upper Devonian. [7058] Brushford, North Devon.

(See also *P. cryptophthalmus*.)

BRYOZOA.

Fenestella antiqua †, Lonsdale.

J. Phillips, Pal. Foss., pl. xii., f. 35 a, p. 24.

Lower Devonian. [6876] West Lee, near Lynton, North Devon.

Fenestella arthritica, var. γ , Phillips.

T.

J. Phillips, Pal. Foss., pl. xii., f. 36, p. 25.

Middle Devonian. [7108] Hope, Torquay.

Gorgonia ripisteria, Goldfuss.

J. Phillips, Pal. Foss., pl. xi., f. 30 a, b, p. 20.

Lower Devonian. [6877] Mudstone Bay, South Devon.

Hemitrypa oculata, Phillips.

T.

J. Phillips, Pal. Foss., pl. xiii., f. 38 a, p. 27.

Middle Devonian. [7109] Hope, Torquay.

Millepora similis, Phillips.

T.

J. Phillips, Pal. Foss., pl. xi., f. 32, p. 21.

Middle Devonian. [7110] Hope, Torquay.

BRACHIOPODA.

Athyris (Cleiothyris) Roissyii, L  veill  .

G. F. Whidborne, Mon. Pal. Soc., 1897, pl. xviii., figs. 1, 2, 2 a, p. 148.

(See also ? *Terebratula elongata*.)

Upper Devonian. [6994, 6995] Croyde, Devon.

Athyris phal  na. *Vide Spirifera*.**Atrypa desquamata** (J. de C. Sowerby).

J. Phillips, Pal. Foss., pl. xxxiii., f. 146 a, p. 82.

Middle Devonian. [6911] Newton Bushel.

Atrypa flabellata, Goldf. MS.

T. Davidson, Mon. Pal. Soc., 1865, pl. xi., figs. 10, 10 a, 12 a, b, p. 59.

Middle Devonian. [6912] Wolborough, Newton.

Atrypa lens. *Vide Orthis*.

Atrypa reticularis (Linnaeus), var. **aspera**, Schlotheim.

T. Davidson, Mon. Pal. Soc., 1865, pl. x., figs. 5, 5 a, p. 57.
Middle Devonian. [6918] Newton Bushel.

[**Atrypa**.]

J. Phillips, Pal. Foss. pl. lx., f. 148, * p. 231. Refigured as **Pentamerus brevirostris**, Phillips : T. Davidson, Mon. Pal. Soc., 1865, pl. xv. f. 8, p. 72.
Middle Devonian. [6885] Wolborough, Newton Bushel.

Chonetes margaritacea, Whidborne.

T.

G. F. Whidborne, Mon. Pal. Soc., 1898, pl. xxii., figs. 5, 5 a, 6, p. 179.
Upper Devonian. [6999] Braunton.

Cyrtina heteroclita. *Vide Spirifera*.**Davidsonia Verneuilii**, Bouchard.

T. Davidson, Mon. Pal. Soc., 1865, pl. xi., figs. 14, 14 a, p. 74.
Middle Devonian. [6906] Orchard Quarry, Dartington.
T. Davidson, Mon. Pal. Soc., 1865, pl. xv., f. 18, p. 74.
Middle Devonian. [6905] Newton Bushel.

Discina nitida (Phillips).

T. Davidson, Mon. Pal. Soc., 1865, pl. xx., f. 10, p. 104.
Upper Devonian (Marwood Beds). [6989] West Angle Bay (S. side).
G. F. Whidborne, Mon. Pal. Soc., 1898, pl. xxii., f. 12, p. 183.
Upper Devonian. [6988] Barnstaple.

Leptæna analoga (Phillips).

J. Phillips, Pal. Foss., pl. xxiv., f. 93 a, p. 56.
Upper Devonian. [6993] Croyde Bay, Devon.

Leptæna laxispina (Phillips).

J. Phillips, Pal. Foss., pl. xxv., f. 99, p. 59. Refigured as **Strophalosia productoides**, Murchison : Davidson, Mon. Pal. Soc., 1865, pl. xix., f. 15, p. 97.
Upper Devonian. [7001] Petherwin, Cornwall.

Leptæna membranacea, Phillips.

T.

J. Phillips, Pal. Foss., pl. xxv. f. 101 a, s, p. 60.
Upper Devonian (Pilton Group). [7002] Pilton, N. Devon.

Leptæna nodulosa, Phillips.

T.

J. Phillips, Pal. Foss., pl. xxiv., f. 94 a, b, p. 56.
Middle Devonian. [6907, 6908] Hope, Torquay.

Orthis hipparionyx, Vanux. and Hall.

T. Davidson, Mon. Pal. Soc., 1865, pl. xvii., f. 9, p. 90.
Lower Devonian. [6865] Looe, Cornwall.

Orthis interlineata, J. de C. Sowerby.

T. Davidson, Mon. Pal. Soc., 1865, pl. xvii., f. 18, p. 91.
Upper Devonian. [6990] Landlake, Cornwall.
T. Davidson, Mon. Pal. Soc., 1865, pl. xvii., figs. 20, 22, p. 91.
Upper Devonian. [6991, 6992] Petherwin, Cornwall.

Orthis interstitialis, Phillips.

T.

J. Phillips, Pal. Foss., pl. xxv., f. 103 d, p. 61.
Middle Devonian. [6909] Barton, South Devon.

Orthis lens, Phillips.

J. Phillips, Pal. Foss. xxvi., f. 100 *a*, *b*, p. 65. Refigured as **Atrypa lens**,
T. Davidson, Mon. Pal. Soc., 1865, pl. x, figs. 1, 1 *a-d*, p. 51.
Middle Devonian. [6914] Hope, Torquay.

Orthis longisulcata, Phillips.

T.

J. Phillips, Pal. Foss., pl. xxvi., f. 105 *a*, p. 62.
Lower Devonian. [6864] Watersmeet, N. Devon.

Pentamerus brevirostris (Phillips).

T. Davidson, Mon. Pal. Soc., 1865, pl. xv., figs. 1, 1 *a*, *b*, p. 72. (See also
Terebratula cassidea, *Strigocephalus*, and [*Atrypa*].)
Middle Devonian. [6889] Wolborough, Newton.

Productus prælongus, J. de C. Sowerby.

T. Davidson, Mon. Pal. Soc., 1865, pl. xix., f. 24, p. 102.
Upper Devonian (Pilton Beds). [6998] Croyde Bay, N. Devon.

Retzia ferita. *Vide Terebratula*.**Rhynchonella acuminata** (Martin).

T. Davidson, Mon. Pal. Soc., 1865, pl. xiii., figs. 1, 1 *a*, *b*, p. 60.
Middle Devonian. [6890] Newton Bushel.

Rhynchonella angularis. *Vide Terebratula*.**Rhynchonella bifera** (Phillips).

T. Davidson, Mon. Pal. Soc., 1865, pl. xii., f. 11, p. 64. (See also *Tere-*
bratula.)
Middle Devonian. [6893] Hope, Torquay.

Rhynchonella laticosta (Phillips).

T. Davidson, Mon. Pal. Soc., 1865, pl. xiv., f. 2, p. 61. (See also
Terebratula.)
Upper Devonian (Marwood Beds). [7010] Sloly, Barnstaple.

Rhynchonella neapolitana, Whidborne.

T.

G. F. Whidborne, Mon. Pal. Soc., 1893, pl. xv., figs. 4, 4 *a*, *b*, p. 129.
Middle Devonian. [6894] Newton.

Rhynchonella ? protracta (J. de C. Sowerby).

T. Davidson, Mon. Pal. Soc., 1865, pl. xiv., figs. 29, 29 *a*, p. 69.
Middle Devonian. [6921] Hope, Torquay.
(See also *Terebratula proboscidalis*.)

Rhynchonella reniformis. *Vide Terebratula subdentata*.**Rhynchonella (Camarotoechia) togata**, Whidborne.

G. F. Whidborne, Mon. Pal. Soc., 1897, pl. xix., f. 15, p. 163.
Upper Devonian (Marwood Beds). [7013] North Devon.
G. F. Whidborne, Mon. Pal. Soc., 1897, pl. xix., f. 16, p. 163.
Upper Devonian. [7011] Marwood.
G. F. Whidborne, Mon. Pal. Soc., 1897, pl. xix., f. 18, p. 163.
Upper Devonian (Marwood Beds). [7012] Barnstaple.

Rhynchonella triloba (J. de C. Sowerby).

T. Davidson, Mon. Pal. Soc., 1865, pl. xii., figs. 4, 6, p. 64.
Middle Devonian. [6895, 6896] Newton Bushel.

Spirifera aperturata, Schlotheim ?

[Doubtful]

J. Phillips, Pal. Foss., pl. xxx., f. 133, p. 77. Refigured as **Spirifera**
canalifera (Valenciennes) : T. Davidson, Mon. Pal. Soc., 1864,
pl. vi., f. 9, p. 26.
Lower Devonian, [6860] Lynton, N. Devon,

Spirifera canalifera. *Vide S. aperturata.*

Spirifera costata, J. de C. Sowerby.

J. Phillips, Pal. Foss., pl. xxx., f. 134 *a*, p. 77. Refigured as **Spirifera speciosa?**, var. **paradoxa**, Schlotheim : Davidson, Mon. Pal. Soc., 1864, pl. viii., f. 11, p. 29.

Middle Devonian. [6922] Hope, Torquay.

Spirifera disjuncta, J. de C. Sowerby.

T. Davidson, Mon. Pal. Soc., 1864, pl. v., f. 6, p. 23. (See also *S. protensa*.)
Middle Devonian. [6917] Wolborough, Newton.

Spirifera disjuncta, var. **barumensis** (Sow. MS.), Salter.

T. Davidson, Mon. Pal. Soc., 1864, pl. vi., f. 2, p. 23.
Upper Devonian (Pilton Beds). [7004] Croyde Bay, N. Devon.

Spirifera heteroclita, DeFrance.

J. Phillips, Pal. Foss., pl. xxix., f. 125 *a, d*, p. 72. Refigured as **Cyrtina heteroclita** : T. Davidson, Mon. Pal. Soc., 1864, pl. ix., f. 6, p. 48.

Middle Devonian. [6919] Newton Bushel.

Spirifera hirundo, Phillips.

T.

J. Phillips, Pal. Foss., pl. xxviii., f. 122 *a, b, c*, p. 71. Refigured as **Athyris phalæna** (Phil.) : T. Davidson, Mon. Pal. Soc., 1864, pl. iii., figs. 21, 21 *a, b*, p. 18.

Lower Devonian. [6869] Hope, Torquay.

Spirifera ostiolata, Schlotheim.

J. Phillips, Pal. Foss., pl. xxx., f. 132 *a, c*, p. 76.
Lower Devonian. [6861] Valley of Rocks, Lynton, N. Devon.

Spirifera phalæna, Phillips.

T.

J. Phillips, Pal. Foss., pl. xxviii., f. 123, p. 71. Refigured as **Athyris phalæna** : T. Davidson, Mon. Pal. Soc., 1864, pl. iii., f. 19, p. 18.

Lower Devonian. [6866] Hope, Torquay.

Spirifera oblitterata, Phillips.

T.

J. Phillips, Pal. Foss., pl. xxxi., f. 135, p. 78 ; G. F. Whidborne, Mon. Pal. Soc., 1897, pl. xix., f. 1, p. 156.

Upper Devonian (Pilton Beds). [6997] Brushford, North Devon.

Spirifera protensa, Phillips.

T.

J. Phillips, Pal. Foss., pl. xxviii., f. 118 *a, b*, p. 69. Refigured as **Spirifer disjuncta**, J. de C. Sowerby : T. Davidson, Mon. Pal. Soc., 1864, pl. v., f. 12, p. 23.

Upper Devonian. [7000] Petherwin, Cornwall.

Spirifera simplex, Phillips.

T.

J. Phillips, Pal. Foss., pl. lx., f. 124 *a* (two figures), p. 71 ; T. Davidson, Mon. Pal. Soc., 1864, pl. vi., figs. 19, 20, p. 46.

Middle Devonian. [6915, 6916] Wolborough, Newton.

Spirifera speciosa (Schlotheim).

T. Davidson, Mon. Pal. Soc., 1864, pl. viii., f. 7, p. 29.

Middle Devonian. [6923] Hope, Torquay.

Spirifera speciosa, var. **paradoxa**, Schlotheim.

T. Davidson, Mon. Pal. Soc., 1864, pl. viii., f. 13, p. 29. (See also *S. costata*.)

Lower Devonian. [6859] Fowey, Cornwall.

Spirifera undifera, Roemer.

T. Davidson, Mon. Pal. Soc., 1864, pl. vii., figs. 4, 4 *a, b*, p. 36.

Middle Devonian. [6924] Newton Bushel.

Spirifera unguiculus (J. de C. Sowerby).

J. Phillips, Pal. Foss., pl. xxviii., f. 119 *b, c*, p. 69.
Upper Devonian. [7003] Petherwin, Cornwall.

Spirifera.

T. Davidson, Mon. Pal. Soc., 1864, pl. viii., f. 12, p. 33.
Middle Devonian (Shales). [6925] West Oggwell, Newton Bushel.

Strigocephalus brevirostris, Phillips.

T.

J. Phillips, Pal. Foss., pl. xxxii., f. 143 *b*, p. 80. Refigured as
Pentamerus brevirostris, T. Davidson, Mon. Pal. Soc., 1865, pl.
xv., figs. 11, 11 *a*, p. 72.
Middle Devonian. [6886] Wolborough, Newton Bushel.

Strigocephalus giganteus (J. de C. Sowerby).

J. Phillips, Pal. Foss., pl. xxxii., f. 142 *b*, p. 80.
Middle Devonian. [6899] Bradley, Newton Bushel.

Stringocephalus Burtini, DeFrance

T. Davidson, Mon. Pal. Soc., 1864, pl. 1, f. 21, p. 11.
Middle Devonian. [6898] Chircombe Bridge, Devon.

Strophalosia productoides, Murchison.

T. Davidson, Mon. Pal. Soc., 1865, pl. xix., figs. 17, 17 *a*, p. 97.
Middle Devonian. [6910] East Oggwell, Newton.

T. Davidson, Mon. Pal. Soc., 1865, pl. xix., f. 20, p. 97.
Upper Devonian. [7002] Petherwin.
(See also *Leptaena laxispina*.)

Terebratula angularis, Phillips.

T.

J. Phillips, Pal. Foss., pl. xxxv., f. 162 *b*, p. 89. Refigured as **Rhynchonella**
angularis: T. Davidson, Mon. Pal. Soc., 1865, pl. xiv., f. 12 *a, b*, p. 68.
Middle Devonian. [6891] Wolborough, Newton.

Terebratula bifera, Phillips.

T.

J. Phillips, Pal. Foss., pl. xxxiv., f. 151 *a, b*, p. 84. Refigured as **Rhyn-**
chonella bifera: Davidson, Mon. Pal. Soc., 1865, pl. xii., f. 10, p. 64.
Middle Devonian. [6892] Hope, Torquay.

Terebratula (Atrypa) cassidea, Dalman.

J. Phillips, Pal. Foss., pl. xxxiv., f. 148 *a, b, c*, p. 83. Refigured as **Penta-**
merus brevirostris (Phillips): T. Davidson, Mon. Pal. Soc., 1865,
pl. xv., figs. 9, 9 *a, b*, 10, 10 *a, b*, p. 72.
Middle Devonian. [6887] Newton Bushel.

? Terebratula elongata (Schlotheim).

T. Davidson, Mon. Pal. Soc., 1864, pl. 1, f. 9, p. 8. Refigured as **Athyris**,
(**Cleiothyris**) **Royssii**, L  veill  : G. F. Whidborne, Mon. Pal. Soc.
1897, pl. xvii., f. 13, p. 148.
Upper Devonian (Marwood Beds). [6996] East Hill, Braunton.

Terebratula ferita, v. Buch.

J. Phillips, Pal. Foss., pl. xxxv., f. 163 *a, b, c*, p. 89. Refigured as **Retzia**
ferita: T. Davidson, Mon. Pal. Soc., 1864, pl. iv., f. 10, p. 21.
Middle Devonian. [6920] Newton Bushel.

Terebratula laticosta, Phillips.

T.

J. Phillips, Pal. Foss., pl. xxxiv., f. 153 *a, b*, p. 85. Refigured as
Rhynchonella laticosta: T. Davidson, Mon. Pal. Soc., 1865, pl. xiv.,
f. 1, p. 61.
Upper Devonian (Marwood Beds). [7005, 7006] Baggy Point, N. Devon.

Terebratula proboscidalis, Phillips.

T.

J. Phillips, Pal. Foss., f. 149, p. 84. Refigured as **Rhynchonella** ?
protracta: T. Davidson, Mon. Pal. Soc., 1865, pl. xiv., f. 30,
p. 69.

Middle Devonian.

[6921] Hope, Torquay.

Terebratula subdentata, J. de C. Sowerby.

J. Phillips, Pal. Foss., pl. xxxv., f. 164, p. 90. Refigured as **Rhynchonella**
reniformis (J. de C. Sowerby): T. Davidson, Mon. Pal. Soc., 1865,
pl. xiii., f. 7, p. 62

Upper Devonian.

[7007] Petherwin, Cornwall.

LAMELLIBRANCHIATA.

Actinopteria hirundella (Whidborne).

T.

G. F. Whidborne, Mon. Pal. Soc., 1892, pl. vi., figs. 5, 5 a, p. 61.

Middle Devonian.

[6902] Newton Bushel.

Actinopteria texturata (Phillips).

G. F. Whidborne, Mon. Pal. Soc., 1892, pl. ix., f. 6, p. 74.

Middle Devonian.

[6882] Newton Bushel.

Avicula damnoniensis, J. de C. Sowerby.

J. Phillips, Pal. Foss., pl. xxiii., f. 91 c, p. 51. (See also *Ptychopteria*.)

Upper Devonian.

[7020] Marwood, N. Devon.

Avicula subradiata, J. de C. Sowerby.

J. Phillips, Pal. Foss., pl. xxi., f. 86, p. 50.

Upper Devonian.

[7017] Petherwin, Cornwall.

Aviculopecten transversus. *Vide Pecten*.**Conocardium clathratum**. *Vide Pleurorhynchus aliformis*.**Crenipecten** ? *Oceani*. *Vide Pecten plicatus*.**Ctenodonta** (*Palæoneilo*) **lirata** (Phillips).

G. F. Whidborne, Mon. Pal. Soc., 1896, pl. xii., f. 12, p. 100. (See also
Nucula, *Sanguinolaria*, and *Pullustra*.)

Upper Devonian (above Marwood Beds). [7022] Baggy, N. Devon.

Ctenodonta (*Koenenia*) cf. **obsoleta** (Goldfuss).

G. F. Whidborne, Mon. Pal. Soc., 1896, pl. xii., f. 10, p. 106.

Upper Devonian (Marwood Beds). [7025] Baggy Point, North Devon.

Ctenodonta ? *tensa*, Whidborne.

T.

G. F. Whidborne, Mon. Pal. Soc., 1896, pl. xii., figs. 9, 9 a, p. 104.

Upper Devonian (Marwood Beds).

[7026] Barnstaple.

Cucullæa amygdalina, Phillips.

T.

J. Phillips, Pal. Foss., pl. xviii., f. 66 a—d, p. 40.

Upper Devonian.

[7034] Marwood, North Devon.

Cucullæa angusta, J. de C. Sowerby.

J. Phillips, Pal. Foss., pl. xix., f. 68 a—c, p. 41.

Upper Devonian.

[7035] Marwood, N. Devon.

Cucullæa depressa, Phillips.

T.

J. Phillips, Pal. Foss., pl. xix., f. 71 a—c, p. 42. Fig. 71 a, b, refigured G. F.

Whidborne, Mon. Pal. Soc., pl. xii., figs. 3, 3 a, p. 111.

Upper Devonian.

[7027, 7028] Marwood.

G. F. Whidborne, Mon. Pal. Soc. 1896, pl. xii., f. 2, p. 111.

Upper Devonian.

[7029] Marwood.

Cucullæa Hardingii, J. de C. Sowerby.

J. Phillips, Pal. Foss., pl. xviii., f. 67 *a, b* ; pl. xix, f. 67 *a, b*, p. 40.
Upper Devonian. [7030-7033] Marwood, North Devon.

Cucullæa trapezium, J. de C. Sowerby.

J. Phillips, Pal. Foss., pl. xix., f. 70, p. 41.
Upper Devonian. [7037] Marwood, North Devon.

Cucullæa unilateralis, J. de C. Sowerby.

J. Phillips, Pal. Foss., pl. xix., f. 69 *a—c*, p. 41. Fig. 69 *c* refigured
G. F. Whidborne, Mon. Pal. Soc., 1896, pl. xiii., figs. 10, p. 109.
Upper Devonian. [7036] Marwood, North Devon.

Cypricardia deltoidea, Phillips. T

J. Phillips, Pal. Foss., pl. xvii., f. 59, p. 37. Refigured as **Myophoria deltoidea** : G. F. Whidborne, Mon. Pal. Soc., 1896, pl. x., figs. 7, 7 *a*, p. 93.
Upper Devonian. [7039] South Petherwin, Cornwall.

Cypricardina reticulata (Phillips).

G. F. Whidborne, Mon. Pal. Soc., 1892, pl. i., f. 12, p. 11.
Middle Devonian. [6932] Newton Bushel.

Cypricardia semisulcata (J. de C. Sowerby). [Doubtful]

J. Phillips, Pal. Foss., pl. xvii., f. 57 *b, c*, p. 36.
Upper Devonian. [7051] Landlake, Cornwall.

Digoniomya elegans, Whidborne. T.

G. F. Whidborne, Mon. Pal. Soc., 1896, pl. xiii., f. 13, p. 117.
Upper Devonian. [7052] Croyde, North Devon.

Goniophora obliqua (Whidborne). T.

G. F. Whidborne, Mon. Pal. Soc., 1892, pl. iii., f. 1, 1 *a, b*, p. 16.
Middle Devonian. [6933] Newton Bushel.

Hoplomytilus crassus, Sandberger.

G. F. Whidborne, Mon. Pal. Soc., 1892, pl. iv., figs. 2, 2 *a*, p. 44.
Middle Devonian. [6904] Newton Bushel.

Leptodesma citimum, Whidborne. T.

G. F. Whidborne, Mon. Pal. Soc., 1897, pl. xiii., figs. 7, 7 *a*, p. 120.
Upper Devonian. [7014] Marwood, N. Devon.

Leptodesma cultellatum, Whidborne. T.

G. F. Whidborne, Mon. Pal. Soc., 1896, pl. xiv., figs. 2, 2 *a*, p. 121.
Upper Devonian (Marwood Beds). [7016] Braunton, N. Devon.

Leptodomus constricta, McCoy.

G. F. Whidborne, Mon. Pal. Soc., 1896, pl. viii., f. 8, p. 75.
Upper Devonian. [7050] Marwood, North Devon.

Mecynodon carinatus (Goldfuss).

G. F. Whidborne, Mon. Pal. Soc., 1892, pl. ii., figs. 15, 15 *a, b*, p. 34.
Middle Devonian. [6926] Newton Bushel ?

Modiola scalaris, Phillips. T.

J. Phillips, Pal. Foss., pl. lx., f. 62*, p. 137.
Middle Devonian. [6931] Berry Pomeroy, Torquay.

Modiolopsis lepida (Whidborne). T.

G. F. Whidborne, Mon. Pal. Soc., 1892, pl. i., f. 5, p. 41.
Middle Devonian. [6930] Newton Bushel.

Modiolopsis sp.

G. F. Whidborne, Mon. Pal. Soc., 1896, pl. xii., f. 7, p. 114.

Upper Devonian (Marwood Beds). [7024] South Cave, Baggy Point.

Myalina damnoniensis. *Vide Mytilus*.**Myalina stulta** (Whidborne).

T.

G. F. Whidborne, Mon. Pal. Soc., 1892, pl. iii., f. 8, p. 48.

Middle Devonian. [6929] Newton Bushel.

Myophoria deltoidea (Phillips).G. F. Whidborne, Mon. Pal. Soc., 1896, pl. x., figs. 5, 5*a*, *b*, p. 93.

Upper Devonian. [7038] Marwood.

G. F. Whidborne, Mon. Pal. Soc., 1896, pl. x., f. 8, p. 93.

Upper Devonian (Marwood Beds). [7040] Sherwell, Barnstaple.

(See also *Cypricardia*.)**Myophoria inflata** (F. A. Roemer).G. F. Whidborne, Mon. Pal. Soc., 1896, pl. x., figs. 3, 3*a*, 4, 4*a*, p. 92.

Old Red Sandstone (Coomhola Grit) [7041, 7042] County Cork.

Myophoria trigona (F. A. Roemer).

G. F. Whidborne, Mon. Pal. Soc., 1896, pl. x., f. 9, p. 96.

Upper Devonian (Marwood Beds). [7043] Croyde Bay.

Mytilarca † *modioloidea*, Whidborne.

T.

G. F. Whidborne, Mon. Pal. Soc., 1896, pl. xiii., f. 8, p. 117.

Upper Devonian (Marwood Beds). [7023] Braunton, North Devon.

Mytilus † *damnoniensis*, Phillips.

T.

J. Phillips, Pal. Foss., 1841, pl. xviii., f. 61, p. 37. Refigured as **Myalina***damnoniensis*: G. F. Whidborne, Mon. Pal. Soc., 1892, pl. iii., f. 6, p. 47.

Middle Devonian. [6928] Newton Bushel.

Nucula latissima, Phillip.

[Doubtful.]

J. Phillips, Pal. Foss. pl. lviii., f. 65,* p. 137. Refigured as **Ctenodonta**(Palæoneilo) *lirata* (Phillips): G. F. Whidborne, Mon. Pal. Soc. 1896, pl. xii., f. 12, p. 100.

Upper Devonian (above Marwood Beds). [7022] Baggy, North Devon.

Nucula ovata, J. de C. Sowerby.

J. Phillips, Pal. Foss., pl. xviii., f. 65, p. 39.

Lower Devonian. [6868] Meadfoot Sands, Torquay.

Pecten granulosus, Phillips.

T.

J. Phillips, Pal. Foss., pl. xxi., f. 75 *a*, *b*, *c*, p. 46.

Upper Devonian. [7008] Landlake, Cornwall.

Pecten plicatus, J. de C. Sowerby.J. Phillips, Pal. Foss., pl. lx., f. 80*, p. 137. Refigured as **Crenipecten** †*Oceani* (Goldfuss): G. F. Whidborne, Mon. Pal. Soc., 1892, pl. x. f. 6, p. 89.

Middle Devonian. [6903] Newton Bushel.

Pecten transversus, J. de C. Sowerby.J. Phillips, Pal. Foss., pl. xxi., f. 77, *a*, *b*, p. 46. Refigured as **Aviculo-***pecten transversus*: G. F. Whidborne, Mon. Pal. Soc., 1896, pl. xvi., f. 2, p. 127.

Upper Devonian (Pilton Beds). [7009] Brushford, N. Devon.

Pleurorhynchus aliformis, J. de C. Sowerby.J. Phillips, Pal. Foss., pl. xvii., f. 51, p. 34. Refigured as **Conocardium***clathratum*, d'Orbigny: G. F. Whidborne, Mon. Pal. Soc., pl. i., f. 20., p. 18.

Middle Devonian. [6927] Newton Bushel.

- Prothyris recta**, Whidborne. T.
 G. F. Whidborne, Mon. Pal. Soc., 1896, pl. ix., figs. 12, 13, 14, p. 86.
 Upper Devonian. [6085a, b, c] South Cave, Baggy, N. Devon.
- Prothyris scalprata**, Whidborne. T.
 G. F. Whidborne, Mon. Pal. Soc., 1896, pl. ix., f. 17, p. 88.
 Upper Devonian. [7044] Barnstaple.
- Pterinea bellula** (Whidborne). T.
 G. F. Whidborne, Mon. Pal. Soc., 1892, pl. iv., f. 11, p. 57.
 Middle Devonian. [6901] Newton Bushel.
- Pterinea ? spinosa**, Phillips. T.
 J. Phillips, Pal. Foss., pl. xxii., f. 81 a, d, p. 48.
 Lower Devonian. [6867] Woodabay, N. Devon.
- Pterinopecten ? Hallii**, Whidborne. T.
 G. F. Whidborne, Mon. Pal. Soc., 1896, pl. xv., f. 4, p. 134.
 Upper Devonian. [7018] Petherwin, Cornwall.
- Pterinopecten polytrichus** (Phillips).
 G. F. Whidborne, Mon. Pal. Soc., 1896, pl. xv., f. 1, p. 132.
 Upper Devonian (Pilton Beds). [7019] Croyde Bay, N. Devon.
- Ptychopteria damnoniensis** (J. de C. Sowerby).
 G. F. Whidborne, Mon. Pal. Soc., 1896, pl. xiv., figs. 9, 9a, p. 126.
 Upper Devonian (Marwood Beds) [7446] West Angle Bay, Pembrokesh.
 G. F. Whidborne, Mon. Pal. Soc., 1896, pl. xiv., figs. 11, 11 a, b, p. 126.
 Upper Devonian. [7021] Marwood.
 (See also *Avicula*.)
- Pullastra antiqua**, J. de C. Sowerby.
 J. Phillips, Pal. Foss., pl. xvii., f. 55 a, b, p. 35. Refigured as
Ctenodonta (Palæoneilo) lirata (Phillips): G. F. Whidborne, Mon.
 Pal. Soc., 1896, pl. xiii., f. 4, p. 100.
 Upper Devonian (Pilton Beds). [7023] Barnstaple.
- Pullastra ? complanata**, J. de C. Sowerby. [Doubtful]
 J. Phillips, Pal. Foss., pl. xvii., f. 56, p. 35. Refigured as **Sphenotus**
Hicksii, T. G. F. Whidborne, Mon. Pal. Soc., 1896, pl. ix., f. 9,
 p. 83.
 Upper Devonian (Marwood Beds). [7049] Barnstaple.
- Rutotia elliptica** (Whidborne). T.
 G. F. Whidborne, Mon. Pal. Soc., 1892, pl. v., f. 3, p. 55.
 Middle Devonian. [6900] Newton Bushel.
- Sanguinolaria elliptica**, Phillips. T.
 J. Phillips, Pal. Foss., pl. xvii., f. 53 a--d, p. 34.
 Upper Devonian (Pilton Beds). [7045, 7046] Combe, Ashburton.
- Sanguinolaria lirata**, Phillips. T.
 J. Phillips, Pal. Foss., pl. lviii., f. 53* a, b, p. 136. Refigured as
Ctenodonta (Palæoneilo) lirata: G. F. Whidborne, Mon. Pal. Soc.,
 1896, pl. xiii., f. 1, p. 100.
 Upper Devonian (Pilton Beds). [7024] Pilton, N. Devon.
- Sanguinolaria sulcata**, Muenster. [Doubtful]
 J. Phillips, Pal. Foss., pl. xvii., f. 52 b, p. 34.
 Upper Devonian (Pilton Beds). [7048] Combe, Ashburton.
- Sanguinolites mimus**, Whidborne. T.
 G. F. Whidborne, Mon. Pal. Soc., 1896, pl. ix., f. 4, p. 78.
 Upper Devonian (Marwood Beds) [7047] Near Croyde.

- Scaldia ? longa**, Whidborne. T.
 G. F. Whidborne, Mon. Pal. Soc., 1896, pl. x., figs. 1, 1 a, 2, p. 89.
 Upper Devonian (Marwood Beds) [7025] South Cave, Baggy Point.
- Sphenotus Hicksii**. *Vide Pullastra ? Complanata*. T.

GASTEROPODA.

- Acroculia sigmoidalis**, Phillips. T.
 J. Phillips, Pal. Foss., pl. xxxvi., f. 170, p. 94.
 Middle ? Devonian [6883] Hope, Torquay.
- Acroculia vetusta**, J. de C. Sowerby.
 J. Phillips, Pal. Foss., pl. xxxvi., f. 169 b, p. 93. Refigured as **Capulus contortus ?** (F. A. Roemer): G. F. Whidborne, Mon. Pal. Soc., 1891, pl. xxii., figs. 6, 6 a, b, p. 218.
 Middle Devonian. [6957] Newton Bushel.
- Antitrochus arietinus**, Whidborne. T.
 G. F. Whidborne, Mon. Pal. Soc., 1891, pl. xxiii., figs. 11-13, p. 235.
 Middle Devonian. [6964-6] Newton Bushel.
- Bellerophon imperforatus**, Whidborne. T.
 G. F. Whidborne, Mon. Pal. Soc., 1892, pl. xxxi., figs. 11, 11 a, p. 329.
 Middle Devonian. [6936] Newton Bushel.
- Bellerophon labyrinthodes**, Whidborne. T.
 G. F. Whidborne, Mon. Pal. Soc., 1896, pl. viii., figs. 2, 2 a, b, p. 63.
 Upper Devonian. [7061] Baggy Point, N. Devon.
- Bellerophon lineatus**, Goldfuss, MS.
 G. F. Whidborne, Mon. Pal. Soc., 1892, pl. xxxi., figs. 6, 6 a, b, p. 321.
 Middle Devonian. [6937] Newton Bushel.
- Bellerophon subglobatus**, M'Coy.
 G. F. Whidborne, Mon. Pal. Soc., 1896, pl. viii., figs. 3, 3 a, p. 64.
 Upper Devonian (Marwood Beds). [7062] North Devon.
- Bellerophon Urii**, ^Fleming.
 J. Phillips, Pal. Foss., pl. xl., f. 199 a-d, p. 106. Refigured as **Euphemus barumensis**, Whidborne, Mon. Pal. Soc., 1896, pl. vii., f. 2, p. 70.
 Upper Devonian (Marwood Beds). [7063] Baggy Point, N. Devon.
- Capulus contortus ?** (F. A. Roemer).
 G. F. Whidborne, Mon. Pal. Soc., 1891, pl. xxii., figs. 5, 5 a, b, p. 218.
 (See also *Acroculia vetusta*.)
 Middle Devonian. [6956] Newton Bushel.
- Capulus cordatus** (Whidborne). T.
 G. F. Whidborne, Mon. Pal. Soc., 1891, pl. xxi., figs. 1, 1 a, p. 212.
 Middle Devonian. [6958] Newton Bushel.
- Capulus galeritus**, Whidborne. T.
 G. F. Whidborne, Mon. Pal. Soc., 1891, pl. xxii., f. 3, 3 a, p. 217.
 Middle Devonian. [6959] Newton Bushel.
- Capulus puellaris**, Whidborne. T.
 G. F. Whidborne, Mon. Pal. Soc., 1891, pl. xx., f. 13, 13 a, p. 210.
 Middle Devonian. [6960] Newton Bushel.

- Euomphalus annulatus**, Phillips. T.
 J. Phillips, Pal. Foss., pl. lx., f. 172*, p. 138. (*E. annulosus* on p. 231);
 G. F. Whidborne, Mon. Pal. Soc., 1891, pl. xxiv., figs. 6, 6 a, p. 250.
 Middle Devonian. [6950] Newton Bushel.
- Euomphalus circularis**, Phillips. T.
 J. Phillips, Pal. Foss., pl. xxxvi., f. 171, p. 94.
 Middle Devonian. [6982] Newton Bushel.
- Euomphalus germanus** (Phillips).
 G. F. Whidborne, Mon. Pal. Soc., 1892, pl. xxv., figs. 4, 4 a, p. 256.
 (See also *Nautilus germanus*.)
 Middle Devonian. [6951] Newton Abbot.
- Euomphalus Hecale**, Hall.
 G. F. Whidborne, Mon. Pal. Soc., 1891, pl. xxiv., figs. 7, 7a, p. 247.
 Middle Devonian. [6953] Newton Bushel.
- Euomphalus radiatus** ? Goldfuss MS.
 J. Phillips, Pal. Foss., pl. lx., f. 171*, p. 138. Refigured as **Euomphalus**
rota, Sandberger : G. F. Whidborne, Mon. Pal. Soc., 1892, pl. xxv.
 f. 8, p. 258.
 Middle Devonian. [6952] Newton Bushel.
- Euomphalus rota**. *Vide E. radiatus* ?
- Euomphalus serpens**, Phillips. [Doubtful]
 J. Phillips, Pal. Foss., pl. xxxvi., f. 172, p. 94.
 Upper Devonian (Pilton Beds). [7069] Brushford, N. Devon.
- Euphemus barumensis**. *Vide Bellerophon Urii*.
- Flemingia perversa** (Whidborne). T.
 G. F. Whidborne, Mon. Pal. Soc., 1892, pl. xxvii., figs. 4, 4 a, p. 267.
 Middle Devonian. [6962] Newton Bushel.
- Helminthochiton papilio** (Whidborne). T.
 G. F. Whidborne, Mon. Pal. Soc., 1892, pl. xxxi., f. 15, p. 334.
 Middle Devonian [6935] Newton Bushel.
- Holopella costata**, Sandberger.
 G. F. Whidborne, Mon. Pal. Soc., 1891, pl. xviii., figs. 15, 15 a, p. 229.
 Middle Devonian. [6967] Newton Bushel.
- Holopella tenuisulcata**, Sandberger.
 G. F. Whidborne, Mon. Pal. Soc., 1891, pl. xviii., f. 11, p. 225.
 Middle Devonian. [6963] Newton Bushel.
- Loxonema anglicum**, d'Orbigny.
 G. F. Whidborne, Mon. Pal. Soc., 1896, pl. v., f. 6, p. 43.
 Upper Devonian (Marwood Beds). [7073] Braunton Down, N. Devon.
- Loxonema ? præterita**, Phillips. T.
 J. Phillips, Pal. Foss., pl. xxxviii., f. 187 c, p. 100.
 Middle Devonian. [6884] Hope, Torquay.
 J. Phillips, Pal. Foss., pl. xxxviii., f. 187 a, b, p. 100. Refigured as
Loxonema reticulatum (Phillips) : G. F. Whidborne, Mon. Pal.
 Soc., 1891, pl. xviii., f. 2, p. 177.
 Middle Devonian. [6977, 6978] Chudleigh, Devon.
- Loxonema priscum** (Muenster).
 G. F. Whidborne, Mon. Pal. Soc., 1891, pl. xviii., f. 17, p. 181.
 Middle Devonian. [6970] Newton Bushel.

- Loxonema reticulata**, Phillips. T.
 J. Phillips, Pal. Foss., pl. lx., f. 187*, p. 139; G. F. Whidborne, Mon. Pal. Soc., 1891, pl. xviii., figs. 3, 3 a, b, p. 177.
 Middle Devonian. [6972] Newton Bushel.
 G. F. Whidborne, Mon. Pal. Soc., 1891, pl. xviii., f. 1, p. 177.
 Middle Devonian. [6971] Newton Bushel.
 (See also *L. ? præterita*.)
- Loxonema Roemeri**, Kayser.
 G. F. Whidborne, Mon. Pal. Soc., 1891, pl. xvii., figs. 18, 18 a, p. 172.
 Middle Devonian. [6973] Newton Bushel.
- Loxonema sinuosa** (J. de C. Sowerby). [Doubtful.]
 J. Phillips, Pal. Foss., pl. xxxviii., f. 182, p. 99.
 Upper Devonian. [7074] South Petherwin, Cornwall.
- Macrocheilus arcuatus**? Phillips. T.
 J. Phillips, Pal. Foss., pl. lx., f. 194,* p. 139. Refigured as **Macrochilina subcostata** (Schlotheim): G. F. Whidborne, Mon. Pal. Soc., 1891, pl. xvi., f. 3, p. 159.
 Middle Devonian. [6979] Newton Bushel.
- Macrocheilus elongatus**, Phillips. T.
 J. Phillips, Pal. Foss., pl. xxxix., f. 195, p. 104. Refigured as **Macrochilina subcostata** (Schlotheim): G. F. Whidborne, Mon. Pal. Soc., 1891, pl. xvi., f. 7, p. 159.
 Middle Devonian. [6976] Newton Bushel.
- Macrochilina elevata**, Whidborne. T.
 G. F. Whidborne, Mon. Pal. Soc., 1891, pl. xvii., figs. 12, 12 a, p. 170.
 Middle Devonian. [6974] Newton Bushel.
- Macrochilina imbricata** (J. de C. Sowerby).
 G. F. Whidborne, Mon. Pal. Soc., 1891, pl. xvii., f. 2, p. 164.
 Middle Devonian. [6975] Newton Bushel.
- Macrochilina subcostata.** *Vide Macrocheilus arcuatus?* and **M. elongatus.**
- Macrochilina ventricosa** (Goldfuss).
 G. F. Whidborne, Mon. Pal. Soc., 1891, pl. xvii., figs. 8, 8 a, 9, p. 167.
 Middle Devonian. [6980, 6981] Newton Bushel.
- Michelia** sp.
 G. F. Whidborne, Mon. Pal. Soc., 1891, pl. xviii., f. 6, p. 183.
 Middle Devonian. [6984] Newton Bushel.
- Murchisonia geminata**, Phillips.
 J. Phillips, Pal. Foss., pl. xxxix., f. 190, p. 102. Refigured as **Murchisonia turbinata** (Schlotheim): G. F. Whidborne, Mon. Pal. Soc., 1892, pl. xxx., f. 11, p. 306.
 Middle Devonian. [6941] Newton Bushel.
- Murchisonia spinosa** (J. de C. Sowerby).
 J. Phillips, Pal. Foss., pl. xxxix., f. 192 b, c, p. 102. Refigured as **Murchisonia turbinata** (Schlotheim): G. F. Whidborne, Mon. Pal. Soc., 1892, pl. xxix., figs. 13, 16, p. 306.
 Middle Devonian. [6939, 6940] Newton Bushel.
- Murchisonia trepomena.** *Vide M. tricineta.*

Murchisonia tricincta (Muenster).

- J. Phillips, Pal. Foss., pl. lx., f. 190*, p. 139. Refigured as **Murchisonia trepomena**, T, Whidborne. Mon. Pal. Soc., 1892, pl. xxx., figs. 16, 16 a, p. 315.
Middle Devonian. [6938] Newton Bushel.

Murchisonia turbinata (Schlotheim).

- G. F. Whidborne, Mon. Pal. Soc., 1892, pl. xxx., f. 8, p. 306. (See also *M. geminata* and *M. spinosa*.)
Middle Devonian. [6942] Newton Bushel.

Murchisonia, sp.

- G. F. Whidborne, Mon. Pal. Soc., 1896, pl. vi., f. 15, p. 60.
Upper Devonian. [7065] Baggy Point, N. Devon.

Naticopsis Hallii, Whidborne.

T.

- G. F. Whidborne, Mon. Pal. Soc., 1896, pl. v., figs. 11, 12, p. 44.
Upper Devonian (Marwood Beds). [7070, 7071] North Devon.

Nautilus germanus, Phillips.

T.

- J. Phillips, Pal. Foss., pl. xlviii., f. 226 a, b, p. 118. Refigured as **Euomphalus germanus**: G. F. Whidborne, Mon. Pal. Soc., 1892, pl. xxv., figs. 4, 4a, p. 256.
Middle Devonian. [6951] Newton Bushel.

Phanerotinus mundus, Whidborne.

T.

- G. F. Whidborne, Mon. Pal. Soc., 1892, pl. xxv., f. 12, p. 261.
Middle Devonian. [6954] Newton Bushel.

Philoxene lævis, d'Archaic and de Verneuil.

- G. F. Whidborne, Mon. Pal. Soc., 1891, pl. xxiii., figs. 18, 18 a, p. 239
Middle Devonian. [6955] Newton Bushel.

Platyostoma ? deforme (J. de C. Sowerby.)

- G. F. Whidborne, Mon. Pal. Soc., 1891, pl. xxiii., figs. 3—5, p. 200.
Middle Devonian. [6961, 6983, 7221] Newton Bushel.

Pleurotomaria antitorquata (Muenster.)

- J. Phillips, Pal. Foss., pl. xxxvii., f. 176 d, p. 96.
Upper Devonian. [7072] South Petherwin, Cornwall.

Pleurotomaria aspera (J. de C. Sowerby).

- J. Phillips, Pal. Foss., pl. xxxvii., f. 177, * p. 96. Refigured as **P. (Gyroma) aspera**: G. F. Whidborne, Mon. Pal. Soc., 1896, pl. vi., f. 12, p. 57.
Upper Devonian. [7067] South Petherwin.

- G. F. Whidborne, Mon. Pal. Soc., 1896, pl. vi., figs. 10, 10 a, b, p. 57.
Upper Devonian (Marwood Beds). [7066] E. of Barnstaple.

- G. F. Whidborne, Mon. Pal. Soc., 1896, pl. vi., f. 11, p. 57.
Upper Devonian. [7068] South Petherwin.

Pleurotomaria cancellata, Phillips.

T.

- J. Phillips, Pal. Foss., pl. xxxvii., f. 176 a, b, p. 96; G. F. Whidborne, Mon. Pal. Soc., 1892, pl. xxviii., f. 4, p. 291.
Middle Devonian. [6881] Newton Bushel.

Pleurotomaria Champernowni, Whidborne.

T.

- G. F. Whidborne, Mon. Pal. Soc., 1892, pl. xxvi., figs. 5, 5 a, p. 277.
Middle Devonian. [6943] Newton Bushel.

Pleurotomaria dissimulatrix, Whidborne.

T.

- G. F. Whidborne, Mon. Pal. Soc., 1892, pl. xxviii., f. 17, p. 300.
Middle Devonian. [6945] Newton Bushel.

Pleurotomaria Lonsdalii, d'Archaic and de Verneuil.

G. F. Whidborne, Mon. Pal. Soc., 1892, pl. xxvii., f. 12, p. 280.
Middle Devonian. [6946] Newton Bushel.

Pleurotomaria neapolitana, Whidborne.

T.

G. F. Whidborne, Mon. Pal. Soc., 1892, pl. xxvii., f. 16, p. 286.
Middle Devonian. [6947] Newton Bushel.

Pleurotomaria subclathrata, Sandberger.

G. F. Whidborne, Mon. Pal. Soc., 1892, pl. xxvii., f. 11, p. 278.
Middle Devonian. [6948] Newton Bushel.

Pleurotomaria subimbricata, Whidborne.

T.

G. F. Whidborne, Mon. Pal. Soc., 1892, pl. xxviii., f. 8, p. 293.
Middle Devonian. [6949] Newton Bushel.

Porcellia bifida (Sandberger).

G. F. Whidborne, Mon. Pal. Soc., 1892, pl. xxxi., figs. 12, 12 *a*, *b*, p. 330.
Middle Devonian. [6944] Newton Bushel.

Scoliostruma textatum. *Vide Turbo*.**Tropidodiscus trilobatus** (J. de C. Sow.), var. **bisulcatus**, F. A. Roemer.

G. F. Whidborne, Mon. Pal. Soc., 1896, pl. viii., f. 6, 6 *a*, p. 68.
Upper Devonian (Marwood Beds). [7064] Baggy Point, N. Devon.

Turbo textatus (Muenster).

J. Phillips, Pal. Foss., pl. xxxvii., f. 175 *a*, *b*, p. 95. Refigured as
Scoliostruma textatum: G. F. Whidborne, Mon. Pal. Soc., 1891,
pl. xxiii., figs. 7, 8, p. 231.
Middle Devonian. [6968, 6969] Newton Bushel.

CEPHALOPODA.

Actinoceras? (*Huronia*) **Crickii**, Whidborne.

T.

G. F. Whidborne, Mon. Pal. Soc., 1896, pl. iv., f. 9, p. 33.
Upper Devonian. [7075] Baggy, N. Devon.

Clymenia fasciata, Phillips.

T.

J. Phillips, Pal. Foss., pl. liii., f. 242 *a-d*, p. 125.
Upper Devonian. [7172] South Petherwin.

Clymenia lævigata, Muenster.

J. Phillips, Pal. Foss., pl. lii., f. 239 *a-c*, p. 124.
Upper Devonian. [7173] South Petherwin.

Clymenia linearis, Muenster.

J. Phillips, Pal. Foss., pl. liii., f. 241 *a*, *b*, p. 125.
Upper Devonian. [7176] South Petherwin.

Clymenia plurisepta, Phillips.

T.

J. Phillips, Pal. Foss., pl. liv., f. 244 *a-c*, p. 126.
Upper Devonian. [7174] South Petherwin.

Clymenia sagittalis, Phillips.

T.

J. Phillips, Pal. Foss., pl. liv., f. 243 *a-c*, p. 125.
Upper Devonian. [7175] South Petherwin.

Clymenia striata (Muenster).

J. Phillips, Pal. Foss., pl. liii., f. 240 *a*, *b*, p. 125.
Upper Devonian. [7082] South Petherwin.

Clymenia valida, Phillips.

T.

J. Phillips, Pal. Foss., pl. liv., f. 245 *a, b*, p. 126.

Upper Devonian.

[7177]

South Petherwin.

Cyrtoceras armatum, Phillips.

T.

J. Phillips, Pal. Foss., pl. xlviii., f. 223 *a, b*, p. 118. Refigured as**Gyroceras armatum**: G. F. Whidborne, Mon. Pal. Soc., 1890, pl.xii., figs. 1, 1 *a*, p. 99.

Middle Devonian.

[7098]

Newton Bushel.

Cyrtoceras? fimbriatum, Phillips.G. F. Whidborne, Mon. Pal. Soc., 1890, pl. x., figs. 3, 3 *a*, p. 104.

Middle Devonian.

[7104]

Newton Bushel.

Cyrtoceras obliquatum, Phillips.

T.

J. Phillips, Pal. Foss., pl. xlv., f. 218 *a, b, d, e*, p. 115. Refigured as**Trochoceras obliquatum**: G. F. Whidborne, Mon. Pal. Soc., 1890,pl. ix., figs. 5, 5 *a, b*, p. 86.

Middle Devonian.

[7120]

Newton Bushel.

Cyrtoceras ornatum? (Goldfuss MS.). Phillips.J. Phillips, Pal. Foss., pl. xlv., f. 217, p. 115. Refigured as **Gyroceras**,**præclarum**, T, Whidborne, Mon. Pal. Soc. 1890, pl. viii., f. 3, p. 91.

Middle Devonian.

[7001]

Newton Bushel.

Cyrtoceras quindecimale, Phillips.

T.

J. Phillips, Pal. Foss., pl. xlv., f. 216, p. 114; G. F. Whidborne, Mon.

Pal. Soc., 1890, pl. x., f. 2, p. 102.

Middle Devonian.

[7106]

Newton Bushel.

Cyrtoceras reticulatum, Phillips.

T.

J. Phillips, Pal. Foss., pl. xlviii., f. 224 *a-c*, p. 117. Refigured as**Trochoceras reticulatum**: G. F. Whidborne, Mon. Pal. Soc., 1890,pl. ix., figs. 7, 7 *a, b*, p. 89.

Middle Devonian.

[7121]

Newton Bushel.

Cyrtoceras rusticum, Phillips.

T.

J. Phillips, Pal. Foss., pl. xlv., f. 222 *a-c*, p. 116.

Upper Devonian.

[7078]

South Petherwin.

Cyrtoceras tredecimale, Phillips.

T.

J. Phillips, Pal. Foss., pl. xlv., f. 215 *a-c*, p. 114. Refigured as**Gyroceras tredecimale**: G. F. Whidborne, Mon. Pal. Soc., 1890pl. x., figs. 5, 5 *a, b*, p. 96.

Middle Devonian.

[7103]

Newton Bushel.

Cyrtoceras n. sp.

G. F. Whidborne, Mon. Pal. Soc., 1890, pl. xii., f. 4, p. 107.

Middle Devonian.

[7105]

Newton Bushel.

Goniatites globosus, Muenster.J. Phillips, Pal. Foss., pl. l., f. 231 *a, b*, p. 120.

Middle Devonian.

[7111]

Newton Bushel.

G. F. Whidborne, Mon. Pal. Soc., 1890, pl. v., figs. 12, 12 *a, b*, p. 67.

Middle Devonian.

[7112]

Newton Bushel.

Goniatites inconstans, Phillips.G. F. Whidborne, Mon. Pal. Soc., 1890, pl. v., figs. 5, 5 *a*, p. 63.

Middle Devonian.

[7113]

Newton Bushel.

Goniatites insignis, Phillips.

T.

J. Phillips, Pal. Foss., pl. xlix., f. 228 *a, b*, p. 119.

Upper Devonian.

[7083]

South Petherwin.

Goniatites obliquus (Whidborne).

T.

G. F. Whidborne, Mon. Pal. Soc., 1890, pl. v., figs. 3, 3 *a*, p. 56
Middle Devonian. [7114] Newton Bushel.

Goniatites transitorius, Phillips.

T.

J. Phillips, Pal. Foss., pl. lx., f. 227,* p. 140; G. F. Whidborne,
Mon. Pal. Soc., 1890, pl. v. figs. 10, 10 *a*, p. 61.
Middle Devonian. [7115] Newton Bushel.

G. F. Whidborne, Mon. Pal. Soc., 1890, pl. vi., figs. 8, 8 *a*, p. 61.
Middle Devonian. [7116] Newton Bushel.

Goniatites sp.

G. F. Whidborne, Mon. Pal. Soc., 1890, pl. vi., figs. 14, 14 *a, b*, p. 75.
Middle Devonian. [7118] Newton Bushel.

G. F. Whidborne, Mon. Pal. Soc., 1890, pl. vi., figs. 15, 15 *a*, p. 76.
Middle Devonian. [7117] Newton Bushel.

Gyroceras armatum. *Vide Cyrtoceras.***Gyroceras Crickii**, Whidborne.

T.

G. F. Whidborne, Mon. Pal. Soc., 1890, pl. x., f. 10, p. 99. (*Cyrtoceras*
on plate.)
Middle Devonian. [7100] Newton Bushel.

Gyroceras Eifelense (d'Arch. and de Vern.).

G. F. Whidborne, Mon. Pal. Soc., 1890, pl. x., f. 8, p. 97.
Middle Devonian. [7097] Newton Bushel.

Gyroceras ornatum (Goldfuss, MS.), Whidborne.

G. F. Whidborne, Mon. Pal. Soc., 1890, pl. viii *A.*, figs. 1, 1 *a*, p. 94.
Middle Devonian? [7099] Newton Bushel?

Gyroceras præclarum (Whidborne).

T.

G. F. Whidborne, Mon. Pal. Soc., 1890, pl. viii., figs. 2, 2 *a*, p. 91. (See
also *Cyrtoceras ornatum*.)
Middle Devonian. [7002] Newton Bushel.

Gyroceras tredecimale. *Vide Cyrtoceras.***Nautilus germanus.** *Vide Euomphalus.***Orthoceras Champernowni**, Whidborne.

T.

G. F. Whidborne, Mon. Pal. Soc., 1890, pl. xv., f. 11, p. 142.
Middle Devonian. [7125] Newton Bushel.

Orthoceras cinctum? J. de C. Sowerby.

J. Phillips, Pal. Foss., pl. xli., f. 204 *a*, p. 109. Refigured as **Orthoceras**
speciosum (Muenster): G. F. Whidborne, Mon. Pal. Soc., 1890,
pl. xv., f. 8, p. 149.
Middle Devonian. [7134] Newton Bushel.

Orthoceras dolatum, Whidborne.

T.

G. F. Whidborne, Mon. Pal. Soc., 1890, pl. xiv., f. 3, p. 132.
Middle Devonian. [7126] Newton Bushel.

Orthoceras ellipsoideum? Phillips.

T.

J. Phillips, Pal. Foss., pl. lx., f. 205,* p. 140. (*O. ventricosum*, on
p. 231.) Refigured as **Poterioceras ellipsoideum**: G. F. Whid-
borne, Mon. Pal. Soc., 1890, pl. xi., figs. 1, 1 *a*, p. 115.
Middle Devonian. [7131] Newton Bushel.

Orthoceras imbricatum, Hisinger.J. Phillips, Pal. Foss., pl. xlii., f. 207, p. 111. Refigured as **Poterioceras** ?

G. F. Whidborne, Mon. Pal. Soc., 1896, pl. iv., f. 5, p. 28.

Upper Devonian. [7079] Marwood, N. Devon.

Orthoceras laterale, Phillips.J. Phillips, Pal. Foss., pl. xli., figs. 205 *c*, *d*, p. 110 ; G. F. Whidborne, Mon. Pal. Soc., 1890, pl. xv., f. 3, p. 144.

Middle Devonian. [7127, 7128] Newton Bushel.

G. F. Whidborne, Mon. Pal. Soc., 1890, pl. xv., figs. 4, 5, p. 144.

Middle Devonian. [7129, 7130] Newton Bushel.

Orthoceras ludense, J. de C. Sowerby.J. Phillips, Pal. Foss., pl. xlii., f. 206 *a*, *b*, p. 110.Upper Devonian. [7076, 7077] (*a*) South Petherwin. (*b*) Marwood.**Orthoceras rapiforme**, Sandberger.G. F. Whidborne, Mon. Pal. Soc., 1890, pl. xiii., figs. 15, 15 *a*, p. 121.

Middle Devonian. [7132] Newton Bushel.

Orthoceras Robertsi, Whidborne.**T.**

G. F. Whidborne, Mon. Pal. Soc., 1890, pl. xiii., f. 11, p. 126.

Middle Devonian. [7133] Newton Bushel.

Orthoceras speciosum. *Vide O. cinctum* ?**Orthoceras subannulare** (Muenster).G. F. Whidborne, Mon. Pal. Soc., 1890, pl. xiv., figs. 7, 7 *a*, p. 138.

Middle Devonian. [7135] Newton Bushel.

Orthoceras tubicinella, J. de C. Sowerby.G. F. Whidborne, Mon. Pal. Soc., 1890, pl. xiv., figs. 4, 4 *a*, p. 134.

Middle Devonian. [7136] Newton Bushel.

Orthoceras Vicarii (Whidborne).**T.**

G. F. Whidborne, Mon. Pal. Soc., 1890, pl. xiii., f. 3, p. 129.

Middle Devonian. [7137] Newton Bushel.

Phragmoceras ? unguatum (Whidborne).**T.**

G. F. Whidborne, Mon. Pal. Soc., 1890, pl. xi., figs. 5, 6, 8, p. 111.

Middle Devonian. [7122-7124] Newton Bushel.

Poterioceras ellipsoideum. *Vide Orthoceras*.**Poterioceras ?** *Vide Orthoceras imbricatum*.**Subclymenia Symondsi** (MS.). Whidborne.**T.**G. F. Whidborne, Mon. Pal. Soc., 1896, pl. vii., figs. 3, 3 *a*, 4, p. 26.

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Temnocheilus inornatus (Whidborne).**T.**G. F. Whidborne, Mon. Pal. Soc., 1890, pl. vii., figs. 3, 3 *a*, p. 80.

Middle Devonian. [7107] Newton Bushel.

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Middle Devonian. [7119] Newton Bushel.

Trochoceras reticulatum. *Vide Cyrtoceras*.

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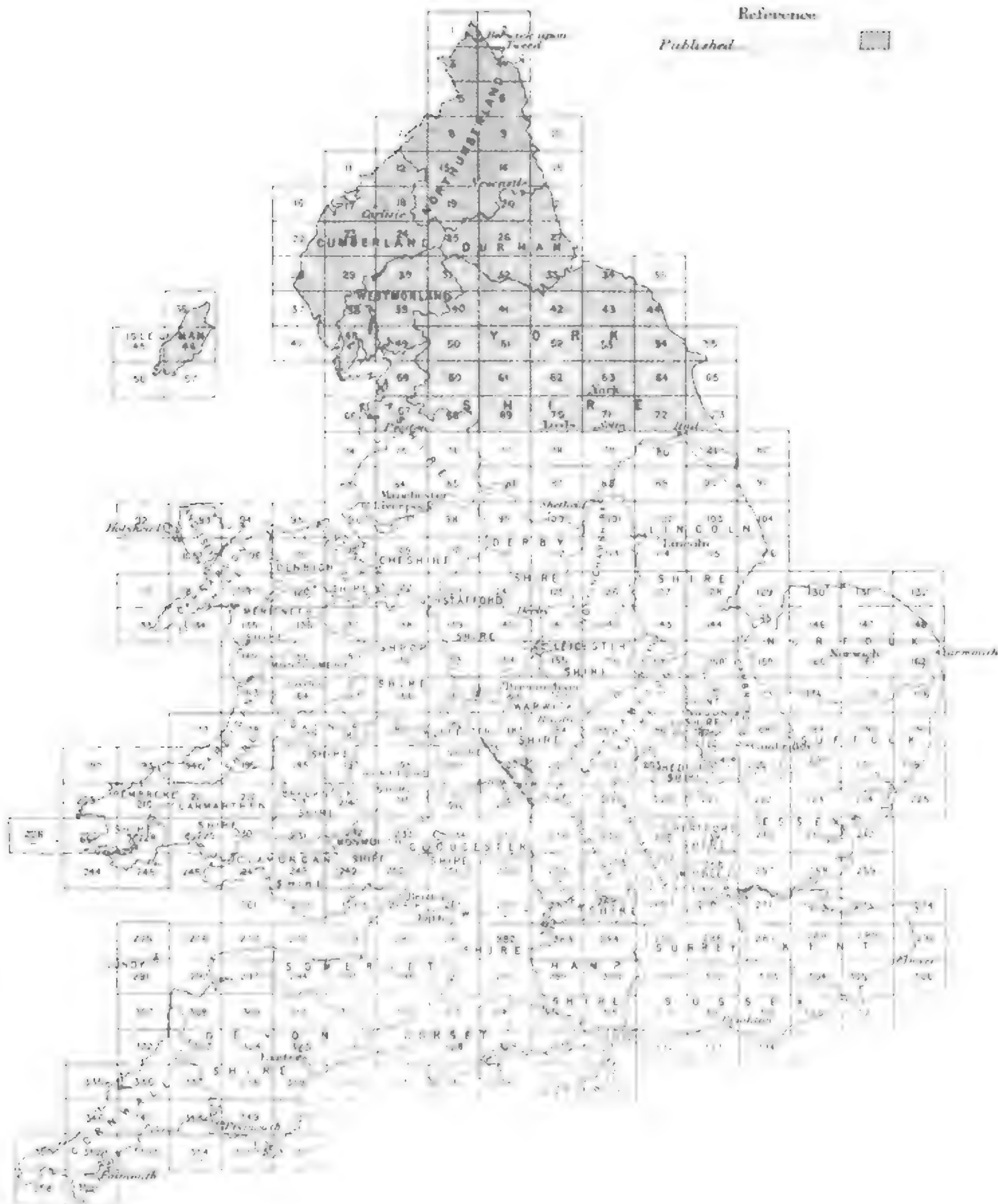
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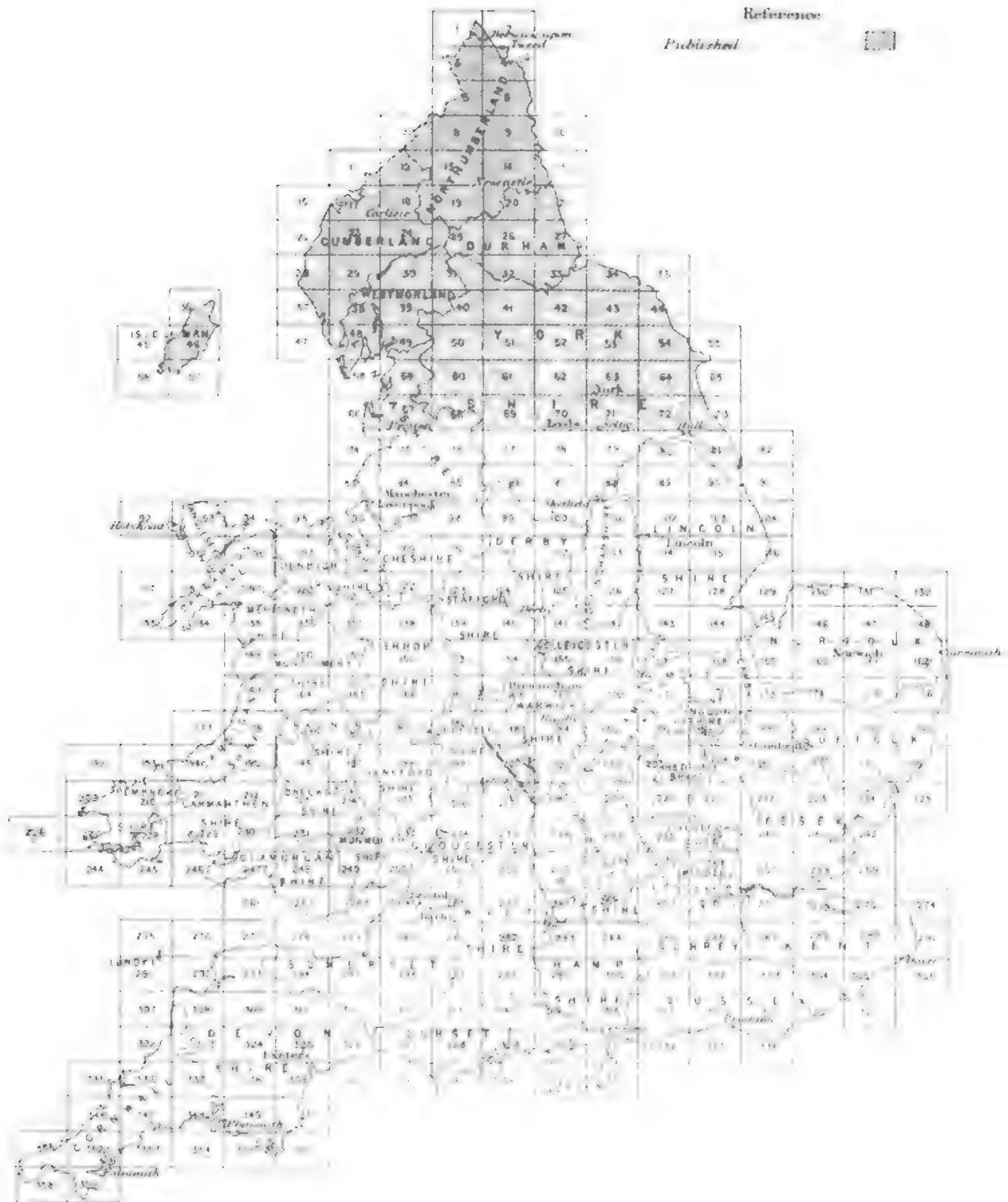
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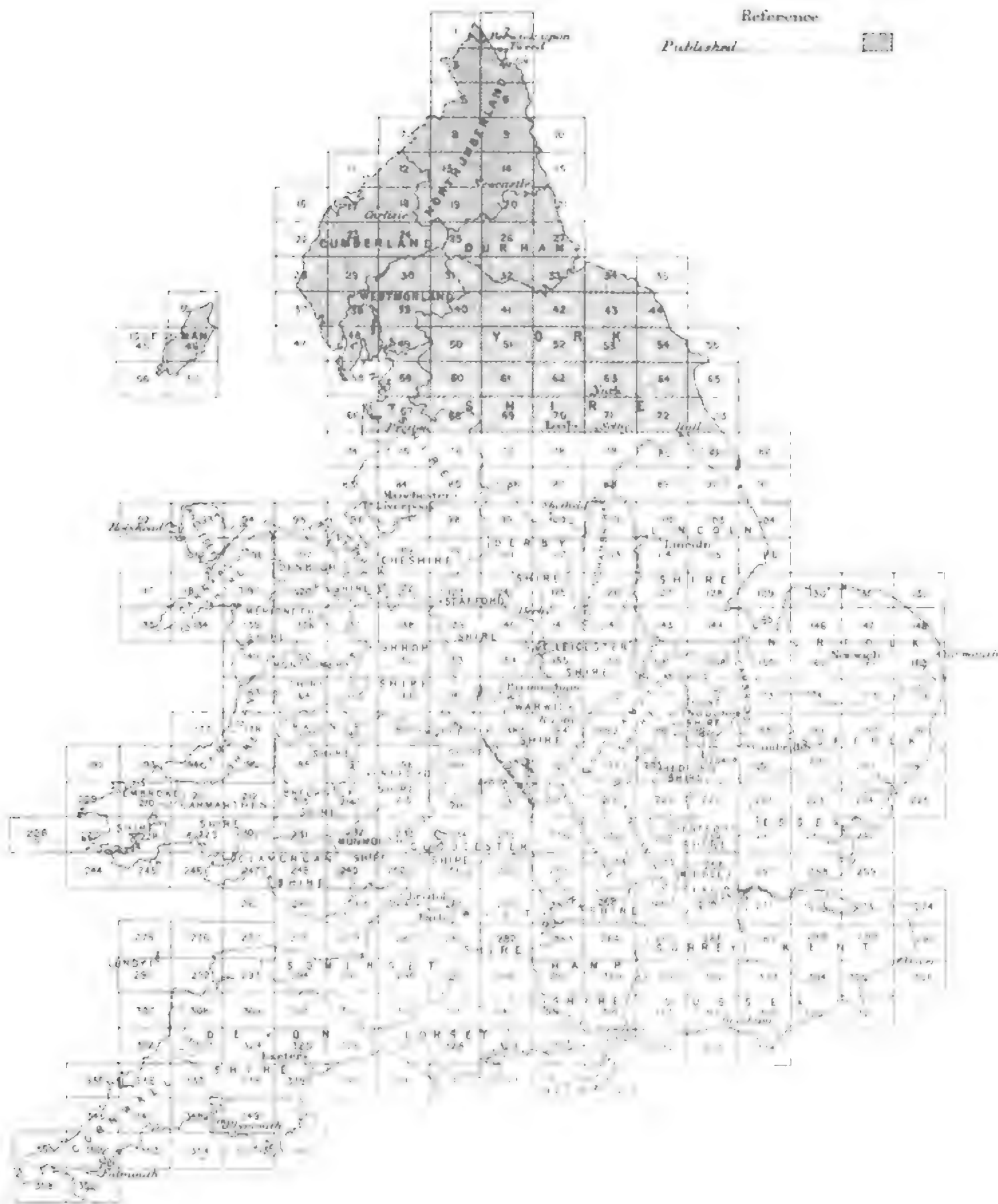
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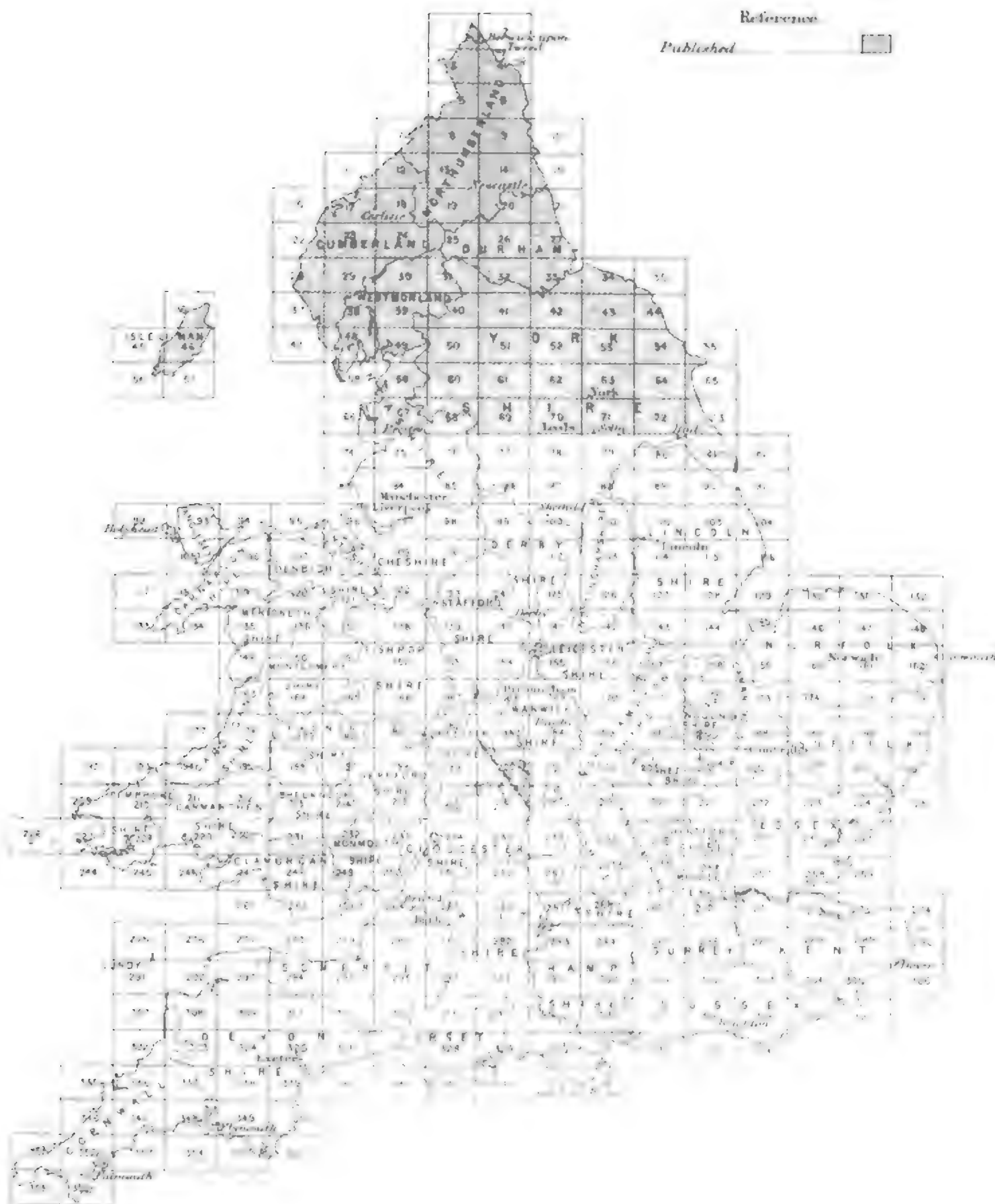
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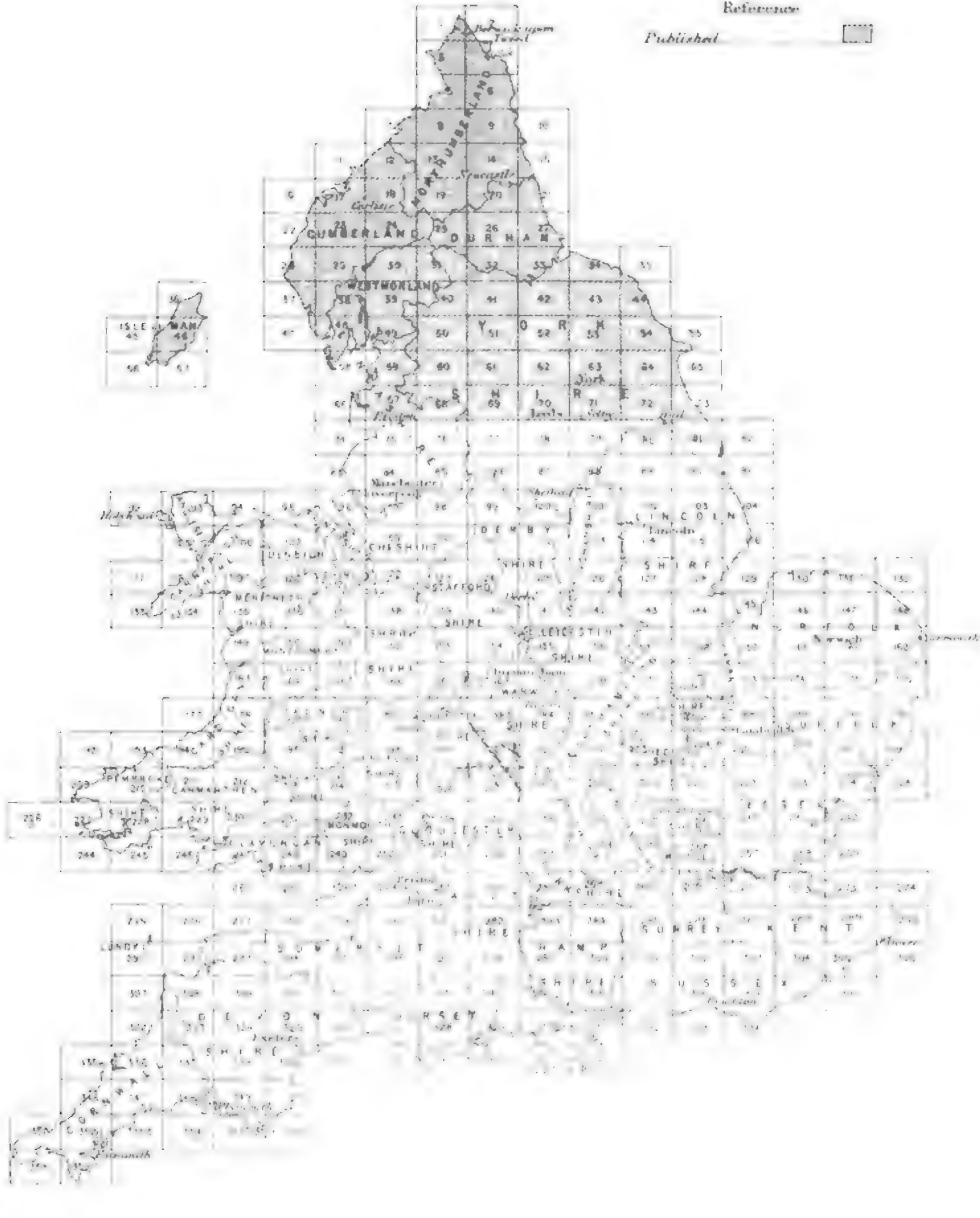
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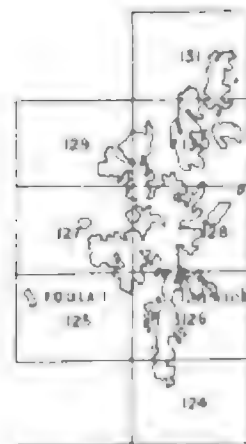
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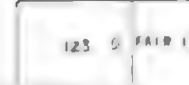
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to the
GEOLOGICAL MAP OF SCOTLAND

Published on the Scale of One Inch to a Mile



SHETLAND ISLANDS



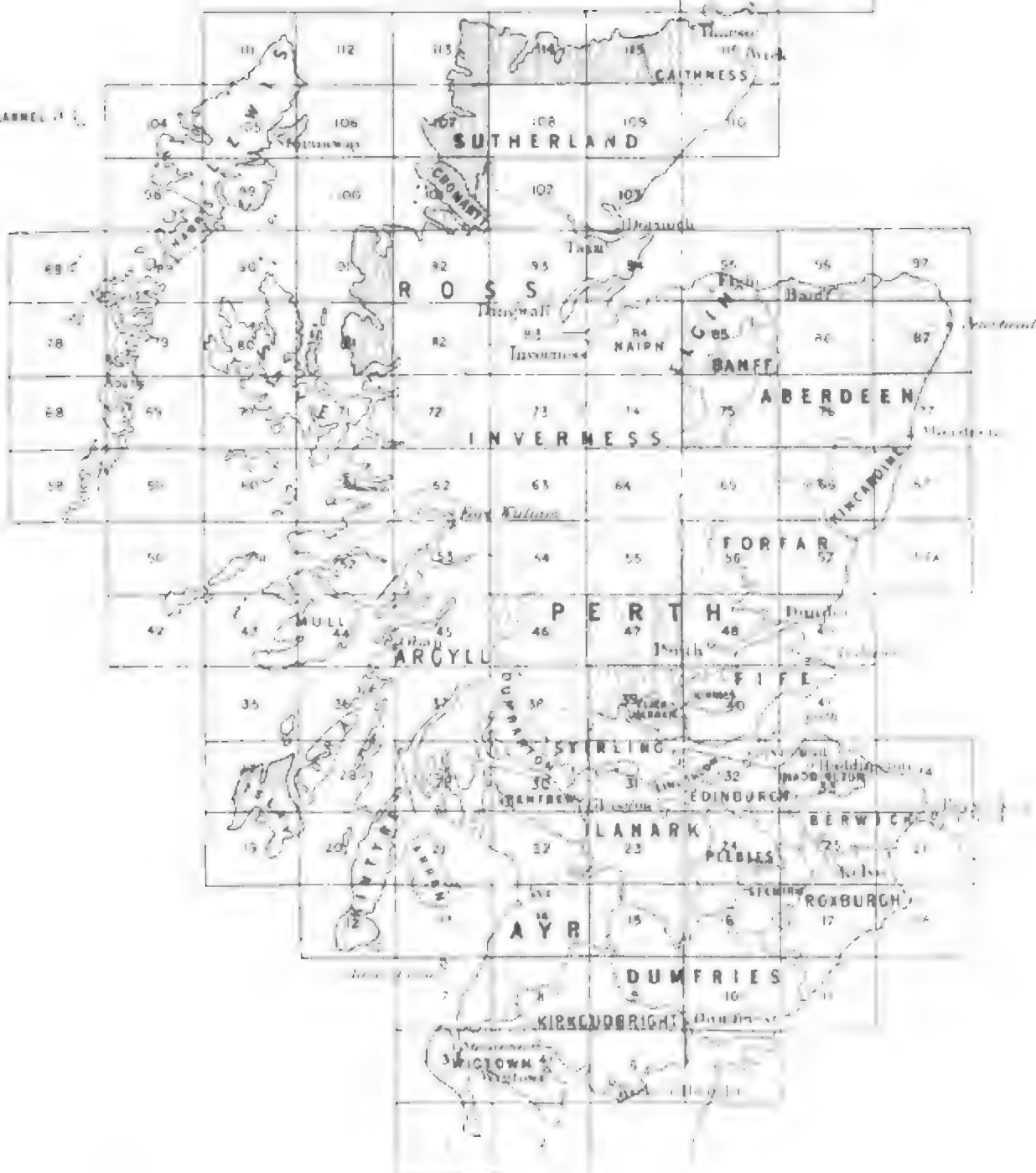
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PLATE 11







MEMOIRS OF THE GEOLOGICAL SURVEY

SUMMARY OF PROGRESS

OF THE

GEOLOGICAL SURVEY

OF THE

UNITED KINGDOM

AND

MUSEUM OF PRACTICAL GEOLOGY

FOR

1901.

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HEREFORDSHIRE.—42 NE, SE, 43, 55, 56 NE, SE..

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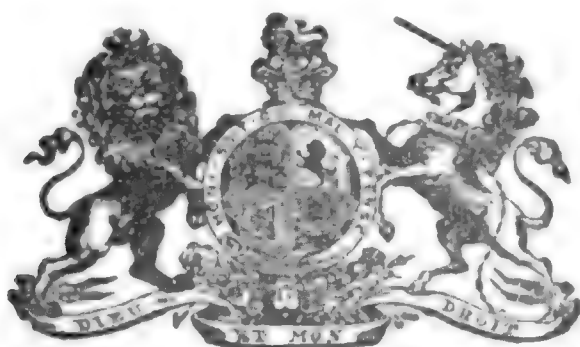
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FOR

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SUMMARY OF PROGRESS

OF THE

GEOLOGICAL SURVEY

AND

MUSEUM

FOR 1901.

INTRODUCTION.

The field work for the year 1901 was concentrated in definite Mr. Teall. areas and was placed under the charge of District Geologists. In view of this method of carrying on the work it has been thought desirable to make the annual record of progress reflect the organisation of the Survey. The chronological arrangement which has been adopted in previous *Summaries* has therefore been abandoned in favour of a geographical arrangement.

The work in England and Wales was under the general charge of Mr. H. B. Woodward, F.R.S., and was carried on in three districts, which are referred to as the Midland district, the Southern district and the South Wales district.

In Scotland the work was superintended by Dr. John Horne, F.R.S., and was of necessity somewhat more scattered. In the following report the results are grouped also under three districts: the West Highland district, including Skye; the Northern district; and the East Highland district.

The work in Ireland, which is limited to a re-survey of the drift-covered areas, was in charge of Mr. G. W. Lamplugh and was carried on in the neighbourhood of Dublin.

A few of the more important results will now be briefly indicated.

In the Midland district the detailed mapping on the six-inch scale has led to some modification of the earlier maps. The so-called Permian outlier west of Rushton has been proved to belong to the Lower Carboniferous series. The Triassic area which forms the greater portion of Sheet 110 is for the most part covered by glacial and fluvio-glacial deposits. Some interesting details as to the nature, distribution and probable mode of origin of these deposits will be found in the following pages.

Mr. Teall.

In the west of England the process of subdividing the great killas-formation of De la Beche has been continued, and a new division—the Hayle Sandstone—has been recognised. There is every reason to hope that as this important work proceeds the structure of the district will be made out and the true relations of the Devonian to the pre-Devonian rocks ascertained.

A considerable mass of granite, later in date than the main mass, has been found in the Land's End district, thus proving that the granitic area is not so simple in structure as is represented in the earlier maps. Special attention has been paid to the metamorphism produced by the granite, not only on account of its scientific interest, but also because the more important mineral veins occur in the metamorphic zone. Some isolated metamorphic areas, which indicate the proximity of granite to the present surface in districts where no granite is visible, have been met with. The work of recording the mining information has been delayed pending the appointment of an officer whose duty it will be to devote himself especially to this object. The appointment has now been made and the work will be proceeded with.

In the Devonian and Carboniferous areas of the west of England additional evidence has been obtained of an important unconformity between the Middle Culm or Wearde beds and the Devonian. The Lower Devonian succession has been worked out in a more satisfactory manner than heretofore.

The progress of the work of mapping the South Wales coal-field has necessitated the examination of the Lower Palæozoic rocks which come within the northern border of Sheet 230. The Ordovician and Silurian rocks which occur within the sheet have been examined, but no natural undisturbed junction has been met with. Evidence of faulting, probably accompanied by over-thrusting, has been found all along the line, and the dominant movements have been connected up with the disturbances of Cribarth and the Vale of Neath to which reference has been made in previous summaries.

Inliers of Silurian rocks, hitherto unsuspected, have been found in Gower, thus proving a great but, probably, local diminution in the thickness of the Old Red Sandstone. No definite separation of Upper and Lower Old Red Sandstone has yet been found possible. The sequence of red beds appears to be conformable throughout; but, on the other hand, there are signs of an unconformity between the Old Red Sandstone and the Silurian rocks.

The deep trough of Coal Measures extending from Swansea to Llanelli has been further examined and found to contain some of the highest measures of the coal-field. Two outliers of Trias have been proved to occur in Gower.

The transportation of glacial drift which has taken place in a general south-westerly direction in the districts previously examined, has had a southerly impulse given to it across the northern and western portion of the Carboniferous area, from which the presence of a great body of ice in Central Wales may be inferred.

In the northern district of Scotland, work has been carried on Mr. Teall, in Ross-shire and Inverness-shire, extending eastwards from Loch Hourn and Loch Ailsh. Much additional information has been obtained as to the crystalline schists and the associated igneous rocks. The Glenelg plutonic complex has been found to consist of acid, intermediate, basic and ultra-basic rocks which have been intruded into the Moine-schists. The more acid members of the series have been sheared and granulitised in certain places by later movements, and dykes of quartz-felsite, porphyrite and mica-trap traverse the complex.

In the Alness district of Ross-shire, a bluish grey mica-schist belonging to the Moine series has been traced into a banded hornfels which forms a contact zone round augen-gneiss. From this it has been inferred that the contact metamorphism was anterior to the movement which produced the foliation in the Moine series. Lenticular sills of hornblendite and two small exposures of the rare and interesting rock known as scyelite have been observed in the same district.

In the West-Highland area, dykes of a dioritic rock precisely resembling the malchites of the Odenwald, have been met with near the head of Loch Eil. They traverse muscovite-biotite-gneiss, amphibolite and pegmatites, but are also cut by thin strings of pegmatite.

In the central district of Scotland, the examination of an area between Pitlochry and Blair Athol has brought to light important evidence bearing on the sequence of the Highland-schists in that area. The graphite schist, which is in many places separated from a mass of black schist by folded quartzite, has been traced continuously round the folds into the black schist, and the identity of the two in that area has, therefore, been established. The quartzite appears to be the highest member of the series, and there is some evidence of an unconformity at its base. Interesting evidence bearing on the age of the newer granite has been obtained. In the Alness district of Ross-shire the basal conglomerate of the Old Red Sandstone contains fragments of these granites, whereas in the region north of Clachlet in Argyllshire, the volcanic series, which is presumably of Lower Old Red Sandstone age, has been pierced by granite. It is not improbable that many of the newer granite masses belong to some portion of the Old Red Sandstone period which is known to have been a period of granitic intrusions in other portions of the British Isles.

The work in the Skye district has led to the recognition of Cretaceous rocks in Soay Sound and Scalpay. The zone of *Pecten asper* has been definitely identified in the latter island, and evidence of the great Upper Cretaceous transgression has thus been found where it had not been hitherto suspected.

An interesting series of composite dykes of Tertiary age has been found in the Lorne Plateau. Some of these have been filled at three successive periods; the earliest intrusion being olivine-dolerite and the latest quartz-felsite. Along one of these composite dykes a series of neck-shaped masses composed of agglomerates and lavas has been mapped.

Mr. Teall.

The detailed mapping of the drifts in Ireland was commenced in the Dublin area. A large portion of this area is deeply covered with drift which, therefore, has a much greater influence on the nature of the surface than the solid geology.

The general composition and distribution of the drifts, the manner in which they have modified the pre-glacial topography in the lower portion of the area, and have, in turn, been modified by this topography in the higher ground, as well as their influence in determining the character of the soil, are briefly summarised in the following pages.

Among the points of interest arising out of last season's work are two which deserve special mention. The esker-like ridge, south of the Liffey, has been found at one point to rest on a water-worn floor of Carboniferous Limestone. At the same locality the gravels of the ridge can be seen to pass laterally into gravelly clay, full of scratched stones, resting on a striated rock surface. These facts strongly support the widely accepted view that ridges of this type are the casts of sub-glacial water-channels.

The examination of the northern slopes of the Dublin Mountains, included within Sheet 112, has led to the conclusion that the short, deep, water-cut gorges, which occur as notches on many of the projecting spurs, like similar gorges recently described in other regions, have been excavated by powerful streams, either draining directly across ice or representing the overflow from lakes held in between the hills on the one side and the margin of the ice-sheet on the other.

I.—ENGLAND AND WALES.

I.—FIELD-WORK.

Mr.
Woodward.

The ground to be surveyed was arranged in three areas under the District Geologists as follows:—

1. Midland district under Mr. C. Fox-Strangways.
2. Southern district under Mr. Clement Reid, F.R.S.
3. South Wales district under Mr. A. Strahan.

In the Midland area the surveys of Sheet 110 (Macclesfield) and of 141 (Derby and Loughborough), together with that of the Cheadle coal-field in Sheet 124, have been finished. The Memoir in Explanation of Sheet 156 (Leicester) has been completed, while those in explanation of Sheets 110 and 141 and district memoirs on the North Staffordshire coal-field, including that of Cheadle, and on the Leicestershire coal-field are in preparation.

In the Southern area, Sheet 351 (Penzance) has been completed with the exception of the mining information. The Memoir in Explanation of Sheet 314 (Ringwood) was finished, and this, as well as memoirs dealing with the geology of Exeter and Southampton, would have been published, but that questions

concerning a uniform price for memoirs have caused delay. Mr. Woodward. The Memoirs on Sheets 298 (Salisbury), 317 (Chichester and Midhurst), 350 (Torquay), and 355 and 356 (Kingsbridge and Start Point) are in hand.

In the South Wales area the survey of Sheet 247 (Swansea) has been completed, but some colliery information has yet to be obtained. The Memoir in Explanation of Sheet 263 (Cardiff) was finished, and other memoirs on Sheets 231 (Merthyr Tydvil), 248 (Pontypridd), and 262 (Bridgend) are in hand.

Proofs of the general memoir on the *Cretaceous Rocks of Britain*, vol. ii., by Mr. Jukes-Browne, and of that on the *Geology of the Isle of Man*, by Mr. Lamplugh, are still in hand. A memoir on the *Water Supply of Berkshire* has been completed, and we are indebted to Mr. H. W. Monckton for editing the MSS. left by the late Mr. J. H. Blake on the geology of the country around Reading in explanation of Sheet 268. The publications during the year are noted on page 94.

In addition to the ordinary field-work, special examinations have been made of new railway cuttings; those from Axminster to Lyne Regis, and from Alderton to Wootton Bassett (on the South Wales Direct Railway) were noted by myself, and the sections exposed by the Goole and Marshland Railway were recorded by Mr. Gibson.

Through the courtesy of Mr. James Mansergh, F.R.S., then President of the Institution of Civil Engineers, Mr. T. C. Cantrill had the opportunity of examining the sections along the course of the aqueduct of the Birmingham Corporation Waterworks from Rhayader to Frankley; and by kind permission of Mr. A. McDonald Cobban, Mr. Gibson was enabled to examine a series of cores from a deep boring at Scunthorpe in Lincolnshire.

1. MIDLAND DISTRICT.—CHESHIRE, STAFFORDSHIRE, AND DERBYSHIRE.

Mr. C. Fox-Strangways, District Geologist.

Mr. W. Gibson

Mr. T. I. Pocock

Mr. C. B. Wedd

Mr. J. Allen Howe

} Geologists.

LOWER CARBONIFEROUS ROCKS (CHESHIRE AND STAFFORDSHIRE).

*These rocks occupy the eastern side of Sheet 110. They are arranged in a series of synclinal and anticlinal folds running in a more or less northerly direction. The northern part of this region has been mapped by Mr. Pocock, and was described in the last *Summary of Progress*; the southern portion has been mainly surveyed by Mr. Wedd, with the exception of the ground north of Rushton Spencer, which has been done by Mr. Howe. Mr. Fox-Strangways.

Mr. Wedd.

The Lower Carboniferous shales and sandstones in this area rise into a well-marked anticline running N. and S. by Lask Edge, High Bent, and Brown Edge. The structure is well shown by the change of dip in the shales and grits in Dingle Brook, which flows round the north end of the ridge; and in the cloughs between Cloud Hill and Rushton, where the anticline appears to be pitching down or dying out northwards. This fold is succeeded on the east by a shallow syncline running approximately N.N.W. on the west side of Rudyard Reservoir, as is well shown by the ridges of the Third and Fourth Grits. East of the reservoir another syncline runs in the same direction between Rudyard and Heaton, the outcropping edges of the Fourth Grit illustrating the structure. Both these synclines appear to be dying out northwards. Between them the relatively narrow valley of the Rudyard Reservoir may be assumed to be occupied by an anticline, perhaps in part cut out by a fault running along the valley. East of the Rudyard-Heaton syncline another anticline running W. of N. brings up the so-called "Yoredale Sandstones" again along the edge of the map.

The folding of the hard Millstone Grits intercalated with soft shales is accompanied by a certain amount of local faulting. A fault with northerly downthrow runs E.N.E. across the Horton syncline through Raecliff Wood, where it displaces the Third Grit; it also probably throws the Third against the Fourth Grit on the east side of the reservoir. A short distance further north there is a similar fault with the same downthrow. Just north of Hollins an E. and W. fault with northerly downthrow crosses the anticline of Lask Edge and is continued on into the Biddulph Valley. The purple grit of Rushton appears to be cut off on the south and thrown against shales by a N.W. fault passing south of the Crown Inn. A N.W. fault passing under Wellbeach House west of Rushton Station seems to throw down the Bunter on the east against Lower Carboniferous, and the eastern boundary of the Bunter is considered by Mr. Wedd to be probably also faulted.

On the top and along the flanks of the anticlinal ridge extending by Lask Edge, High Bent, and Brown Edge, red, purple, and white sandstones are exposed, which are upwards of 20 feet in thickness. These beds are indicated on the old survey map as "Yoredale Sandstones." The same series of sandstones and shales comes to the surface east of the Rudyard syncline. In one of the highest sandstones in this series near Dingle Brook, on the west side of the western anticline, there is a two-inch band of hard grit crowded with casts of small lamellibranchs (*Posiuloniella?*). This band is separated by thin black shales from a higher bed of grit with plant remains. Above this there is a thick series of black shales with hard sandstones and layers of calcareous bullions containing *Goniatites* in abundance; these are well seen in Dingle Brook; and in Lee Wood, Rushton. The shales are succeeded by several grits of the Millstone Grit series, which are more numerous and thicker than in the Biddulph valley. Commencing at the north the lowest grit is seen at Heaton and Fairboroughs. It consists of lavender or grey, flaggy, micaceous

grit with intercalated beds of purple shale, resting on very Mr. Wedd. massive, hard, grey grit, with occasional pebbles. This grit appears to be the so-called "Permian" of the old survey. Though similar in colour to the lavender sandstones of the Keele series of the Upper Coal measures, it is a sharper, harder, and more quartzose grit, weathering to red sand rather than to crimson marl. Though it clearly overlies black shale, Mr. Wedd has not been able to find any section showing its relation to higher beds; but at the same time it conforms markedly in strike and dip to the folding of the Lower Carboniferous shales. The grit, shown on the old map as a small isolated patch of "Permian," some little distance west of Rushton, is clearly a ridge of grit overlying black shales and dipping N.W. in strict unison with the folding of the Lower Carboniferous of the locality, to which it clearly belongs. The general strike of the beds about Lee and Rushton also shows that these so-called Permian beds belong to the Lower Carboniferous series. Near the Inn, a red and purple grit with white blotches, shown on the old map as Bunter, is on the same strike as these beds, and undoubtedly of the same age.

The shallow syncline of Horton, which appears to be diminishing or dying out northwards, will in its northerly continuation occupy the ground between the main anticline of Rushton and the syncline of Heaton, against which latter it is probably faulted, the intervening anticline being mainly cut out. Consequently it may be expected that the beds here will be wrinkled into but slight folds, or will be nearly flat, so that a bed occurring at the surface would remain at or close to the surface for a considerable distance.

A short distance S.S.E. of Rushton Church, lavender grit, similar to that described above, is seen, and it is probably identical with the lowest grit of Heaton (the Fifth Grit). Above this the Fourth Grit bends round with the syncline, and is exposed at Heaton. It is a thick, massive, pink and white, rather coarse-grained grit with seams of small pebbles. This grit re-appears on the west side of the Rudyard Reservoir below the Third Grit in Raecliff Wood, and is repeated by a fault. It bends round in another syncline, and runs south of Horton, where it forms a strong ridge below the Third Grit. Some distance further N.W., below Cloud Hill, two or three thin beds of grit which are close together occupy the same relative position below the Third Grit. These are doubtless the attenuated representatives of the Fourth Grit of Heaton and Horton. On the west side of the Biddulph valley no trace of this grit is seen, so it has doubtless died out.

The highest grit seen in this area is a massive, compact, rather coarse-grained false-bedded red and white grit, with seams of pebbles. It rises in a ridge above the Fourth Grit, and runs from Rudyard Reservoir N.N.E., passing east of Hunt House. On the west side of the reservoir the same grit bends round in a syncline and occupies the high ground of Harpers Gate and Grindlestone Edge.

TRIASSIC (STAFFORDSHIRE AND CHESHIRE).

Mr. Wedd
and
Mr. Howe.

Bunter.—A small patch of Bunter comes into the ground under consideration to the north of Rushton, but the area occupied by the rock is not so extensive as indicated on the old survey map. Mr Wedd finds that it consists of the usual red and mottled sandstone with more or less abundant pebbles. It seems to be brought against the Lower Carboniferous on the west by a fault running N.W. under Welbeach House. It is probably bounded on its eastern side also by a fault. In the river banks above Hug Bridge there is an interesting exposure of these beds which has been mapped by Mr Howe. The upper 20 or 30 feet of these, well seen in Red Pool, consists of soft red sandstone with small pebbles and lenticular patches of red marl of varying size; they pass down gradually into a more marly group, shown in the river bank 200 yards east of Hug Bridge. These red marls, which are described in the memoir on *The Geology of the Country round Stockport, Macclesfield, Congleton and Leek*, p. 36, as of Permian age, are now considered to be the lowermost of the visible Bunter beds; they contain numerous bands and lenticular patches of bleached sandy marl. It is the similarity of these markings to those of the Permian of Manchester that seems to have led previous observers to place these beds in the Permian.

Keuper.—In the western part of the map Mr Gibson has found that the Keuper marl is only exposed on the banks of the River Dane, and in the stream near Belchow House. Messrs. Wedd and Howe also report exposures of Keuper marl along the Wheelock and Weaver with the tributaries the Croco and Wade Brook, and in the deep cloughs north of Congleton. It consists principally of red marl with thin beds of gypsum, and a few thin red and white flags at intervals. The beds are much disturbed and sometimes sharply folded, but there is a general westerly dip.

TRIASSIC AND LIASSIC (DERBYSHIRE).

Mr. Fox-
Strangways.

The revision of the country to the south of Derby in the northern part of the one-inch Map 141 has shown that the only solid strata that come to the surface are the Keuper marl, and two small outliers of Lias and Rhætic beds. The Keuper marl forms rising ground between the Trent and Derwent, as well as to the north of the latter river, and to the east of the Soar. There is, however, very little of interest to note in this formation. It consists of the usual red marls; but in the neighbourhood of Derby it becomes more sandy, although there are no special beds of sandstone that can be separated out, as has been done on the south side of the Trent. Just beyond the northern edge of the map these sandstone beds appear to become rather stronger, and it is probable that they will be able to be traced in that country. At Chellaston, and to the east of the Soar at Thrumpton, Kingston, and Gotham, the Keuper marl contains an important bed of gypsum, which is worked at these places. It varies in thickness,

the average being about 6 feet, but occasionally it is said to be much thicker. Although the gypsum usually dissolves when near the surface, its outcrop can be traced with considerable accuracy for some miles. Mr. Fox-Strangways.

In the neighbourhood of Gotham there are two conspicuous outliers of Lower Lias and Rhætic beds, which constitute the extreme N.W. outcrop of these beds in this district. The dark Rhætic shales have been seen at a few places; and, from the outcrop always occurring on a steep escarpment, is not difficult to trace.

The lowest beds of the Lias form a nearly level surface on the summit of these hills, and the limestone has been quarried at several places, but the beds are not thick enough to be of much commercial value.

PLEISTOCENE (DERBYSHIRE).

In the south-eastern portion of the county there is very little true glacial drift; but the post-glacial beds are very extensive, and of considerable interest. The separation between the two is not easy to define, as will be seen presently.

The principal deposit of Boulder-clay occurs at Chellaston, which is situated at the end of the ridge separating the valley of the Trent from that of the Derwent. It occupies eroded hollows in the marl, and consists of two separate deposits, the included fragments being derived from the north and west in the lower clay, and from the east in the upper. The other patches of Boulder-clay are of no great thickness, and occur along the ridge between Mickleover and Derby; in the low ground south of Derby, and along the rising ground north of Barrow-upon-Trent. A good deal of coarse gravel occurs along the ridge by Mickleover, Littleover, and Derby, but it is not easy to separate it from the general mass of drift. There is also a scattering of pebbles over nearly the whole of the ground; the importance of which, in the absence of sections, it is difficult to estimate. The most important beds are, however, the post-glacial deposits of the Trent and Derwent valleys, which have been ably described by Mr Deeley.* Although Mr Deeley's sub-divisions are in the main correct, it is not easy to follow his correlation of the different beds. There are gravels of three or more periods in these valleys, which more or less resemble ordinary river gravels, and Mr. Fox-Strangways cannot find any evidence that these are "interglacial." The highest gravels may be of late glacial age, having been laid down when glacial conditions still existed in the neighbourhood, but there is no true Boulder-clay over them. They, in fact, form a connecting link between glacial and post-glacial times. The highest of these terraces is about 50 feet or more above the present river flat; and although generally forming a fairly level plain they, in some cases, gradually rise on the inner side quite another 50 feet or more. It is here that they become difficult to separate from glacial beds, and we propose therefore to call them "high level valley gravel."

* *Quart. Journ. Geol. Soc.*, vols. xlii., p. 437, and lii., p. 497.

Mr. Fox-
Strangways.

The principal terrace is from 15 to 20 feet above the modern alluvium, against which it usually terminates in a well-defined bank. On the south side of the Derwent this terrace has a breadth of a mile and a half, and at Allenton contains the remains of *Hippopotamus*.* Below this are other terraces, which merge into the alluvium of the present rivers; so that, although they end off in a steep bank on the higher side, they usually tail off down stream, and cannot be separated from each other.

There are two interesting deposits of lacustrine clay occupying old hollows in the Keuper marl; one of these, Sinfin Moor, has an area of about 2 square miles†; and the other, Gotham Moor, is probably double this size, but the mapping of the latter is not yet completed. The deposit of this latter place is a white marl with much vegetable matter, but the specimens yet obtained are too decayed to be determinable. In the Erewash Valley close to Toton Sidings a stiff marly clay with shells occurs beneath the present alluvium of the stream, in which Mr. Clement Reid notes the following species—

Limnæa (peregra ?).

Valvata piscinalis.

Bithynia tentaculata.

Chrysalis cases (several species).

Daphnia (winter eggs).

Lycopod (spores).

Scirpus lacustris.

The Trent alluvium shows a great number of old river courses, one of which is of historical interest as being mentioned by Shakespeare‡; it is close to the village of Repton, and has a length of about 2 miles.

GLACIAL (CHESHIRE).

Mr. Gibson.

The drift occurring in this district consists of two main types—the older Boulder-clay or true till; and the later fluvio-glacial deposits with which we have principally to deal. As the former of these has been seen at very few places there is little to be said about it. The fluvio-glacial deposits however cover the greater part of the district; and, starting from a level plain of about 150 feet at Crewe and Middlewich, gradually rise about Congleton and Macclesfield, till in the hills beyond they attain an altitude of about 800 feet.

The western part of the district is best described under two divisions—the general flat of Crewe, Sandbach and the country to the north; and the ground bordering the Dane river, which intersects this plain. Mr. Gibson finds that sections are not numerous except in and around the Dane valley; where, however, the sands and clays appear to be of a different origin from those around Sandbach.

* H.H. Arnold Bemrose. *loc. cit.* p. 497.

† Mr. Deeley gives a section of the Sinfin Moor deposits. *loc. cit.* p. 502.

‡ *Henry IV.*, Pt. I., Act iii., Sc. 1.

The sands and clays of the general plain are apparently Mr. Gibson. unstratified, and of very varying thickness, being only a few feet thick at Wheelock and Betchton, and over 70 feet around Sandbach. The relation between the sand and clay is not determinable, but as a rule clay overlies an irregular surface of sand, which is itself deposited on an irregular floor of Keuper marl. A few glaciated boulders occur in the clay, but the sands are remarkably free of pebbles of any kind. The sands attain their maximum thickness at Sandbach, but thin out rapidly on approaching the Weaver valley to the west, or the Dane valley to the north.

Around Crewe, and for some distance to the west, there is a finely laminated clay, but its relation to the beds further north is uncertain. A boring in the town proved 30 feet of sand overlying 150 feet of clay.

In the valley of the Dane south of Cranage Hall, and at the Viaduct, beds of Boulder-clay are seen which are the oldest glacial deposits of the district. They are about 30 feet thick, and consist of stiff, brown clay full of striated stones with numerous fragments of *Turritella* and *Cardium edule*. This till is overlaid by a fine, brown, laminated clay which is seen in a brickpit south of Cotton Hall, and appears occasionally to occupy the lower part of the banks of the Dane and other streams. It is overlaid by a light-coloured stratified sand, which spreads out over the surface of the surrounding plain.

Nearer Congleton Mr. Wedd observes that the drift seen in the cliff-sections of the Dane is only a few feet thick, but away from the Dane the thickness is considerably greater. A well on the west side of Eaton Park showed a thickness of 63 feet without reaching the Keuper marl. It is of the usual character; but, besides the common type of current-bedded sand and gravel, sometimes containing shell fragments, there is a somewhat different deposit of yellow sand occupying flat-bottomed valleys (in many cases flanked by normal moundy drift) or level plains. This sand is entirely free from gravel, and probably has a different origin from that of the ordinary glacial drift. It seems to have been reconstructed out of drift material during the earliest stages of the Dane drainage system. These flat sands are sometimes seen to rest upon Boulder-clay. In the ordinary moundy glacial drift the boulders are much the same as those described in previous reports, Ennerdale granophyre, Eskdale granite, and various types of the Lake District Volcanic series being abundant. Small boulders of crinoidal Carboniferous Limestone are sometimes found, and grey flints occur sparingly.

In the country north of the Dane Mr. Howe finds the same general succession. The greater part of the area is occupied, at the surface, by stiff, brownish, finely laminated clay; the remaining portion is covered by clean yellow sand. About Peover Superior, Allostock, and north of Goostrey a sheet of sand rests persistently on the laminated clay; but about Nether Peover the relation of the two deposits becomes obscure. Along the Crow Brook this order is reversed, and a clay reposes on sand. Some

Mr. Wedd
and
Mr. Howe.

Mr. Wedd
and
Mr. Howe.

of the ground mapped as clay consists of good stiff clay, which is so full of small lenticles of clean sand, that after cultivation the soil assumes quite a sandy aspect. Occasionally these lenticles swell out into rounded hills of sand.

The relation of the Dane valley deposits to those of the rest of the plain has not been made out, from the fact that they are never seen together in any one section, and their outcrop is always a feather edge. It is probable however, that they are more recent, and fill in an old line of drainage across the plain.

As we approach the hills the drift becomes much thinner and very irregular in its distribution. Mr. Wedd finds that the Millstone Grit ridges and the porous Bunter sandstone are generally bare of drift. Both clay and sand lie on the high ground within the syncline of the Fourth Grit south of Heaton, but it is doubtful whether there is any in a similar position within the syncline of the Third Grit of Harper's Gate and Grindlestone Edge. The drift of this tract is on the whole similar in composition to that of the plain, and consists of red and brown stony and often sandy clay, with patches of sand and gravel. Amongst the boulders there is naturally a greater proportion of local Carboniferous material, principally fragments of the Millstone Grit and lower sandstones. Boulders of Carboniferous Limestone also occur, and, in the neighbourhood of Heaton and Rudyard, Bunter pebbles are abundant. No shell fragments have been found in this tract, though they occur in the Biddulph valley. The drift, filling the valleys between the anticlinal and synclinal grit ridges, is for the most part flat or gently sloping with few definite mounds; but at Rushton, about the mouth of the Rudyard valley, it is moundy.

Mr. Pocock.

In the district west of Macclesfield Mr. Pocock observes that the drift, which occurs at the surface over the greater part of the low country, belongs to a stage of the glacial period when the *mer de glace* had retreated from the Pennine Hills, and wide sheets of water stretched along the plain at their foot. The rivers Bollin and Dean, emerging from the upland valleys, coalesced on the lowland, and deposited their silts and gravels in terraces along the flanks of the hills. Some account of one of these terraces, which occurs at about the 500-foot contour, was given in last year's report, where it was stated that the shoreline was situated near a ridge of the Triassic formation which abuts against the Carboniferous rocks three miles south of Macclesfield. But there are indications that the water had previously stood at a higher level, and overflowed the Triassic ridge into the basin of the Dane. A thick deposit of chocolate-coloured brick-clay is found at a level of about 570 feet on the east side of Macclesfield, similar in character to the stratified clay at the 500-foot level. A good section may be seen at a brick pit on the Buxton Road near the canal bridge, where the clay is overlaid by gravel and sand, which formed an ancient delta laid down by a stream emerging from the adjacent valley. Brick-clay at a corresponding level occurs on the west bank of the Bollin near Broken Cross, the inter-

vening valley being cut down to a depth of about 140 feet. Mr. Pocock Although this clay is in some places 40 feet thick, few remnants of it have survived denudation. It was probably of wide extent, and the water in which it was deposited was high enough to overflow the watershed in the Churnet Valley, and connect with the eastern drainage system of England. West of Broken Cross the clay seems to become more stony, which probably indicates that it was formed in a lake between the ice sheet and the Pennine Hills. After the retreat of the waters below the 500-foot level, the river Bollin formed a succession of terraces, on part of which the town of Macclesfield is built. A short distance farther north the river flows outside our area, and its subsequent geological history has not been worked out. After the retreat of the waters below the 500-foot level, the gravel which formed the margin of the lake at the mouth of the Langley valley gave rise to a small brook which flows through Dane's Moss and eventually escapes into the valley of the Dane. Hence the water-parting between the Bollin and the Dane since the glacial period has passed through an old gravel deposited by the former stream. This is a phenomenon frequently exhibited by the small streams in the western part of the area.

The remainder of the drift to be described lies within the drainage basin of the Dane, to the south and west of the Triassic axis before mentioned. The ground level falls gradually from a height of 500 or 600 feet between Alderley and Gawsworth to about 250 feet at Chelford and Withington, and the configuration of these two districts is strongly contrasted. Much of the ground in the former area presents on a small scale the familiar features of hills of circumdenudation and valleys of erosion, which are characteristic of land sculpture among horizontal strata that have been subjected to prolonged denudation; the latter consist of horizontal expanses of clay and sand but little broken, save where the larger streams have cut their channels across them. But the passage from the one type to the other is gradual.

The higher parts of the drift from about 450 feet to 600 feet consist of ridges of sand and gravel, which may be nearly 100 feet thick, with occasional hummocks of clay apparently rising from beneath them. The nature of these deposits is not very clear, partly on account of their denuded condition, and partly from the lack of any good sections.

The group of sand mounds in the parishes of Henbury and Gawsworth may have been formed by the flood waters liberated from the ice sheet, as it retreated further and further from the high ground, while the clay hummocks may be *moraine profonde* formed while it was still in motion on the plain.

At a somewhat lower level the character of the drift becomes more apparent, and phenomena are presented similar to those described in the basin of the Bollin, but on a smaller scale, and of a later geological time. Platforms of clay at successive levels may be traced for considerable distances across the country, the higher ones small and broken, the lower of greater extent.

Mr. Pocock.

As they are followed into the higher ground, these clays disappear between beds of sand and gravel, or are laid against higher platforms. Towards the plain they are cut off by denudation and split up into outliers. These clays are of a chocolate brown colour, rather sandy, and free from pebbles. They are not so conspicuously laminated as some of the clays of the Bollin basin, but they are usually interbedded with sand, and can be followed for considerable distances at a nearly uniform level. They are not more than 20 feet thick, and sometimes much less, especially on their inner margins. Owing to extensive denudation they occupy small areas, though sometimes they exceed in thickness the clays which cover large tracts of the lower ground further west.

A good section of these clays can be seen at Buck's Hill, between Siddington and Thornycroft Park. This is a small round hillock about 300 yards in diameter, the top of which is 410 feet above the sea. A pit on one side shows a bed of sandy brown clay free from stones, about 15 feet thick, resting upon sand. The summit is a rather coarse gravel composed of erratic pebbles resting on an eroded surface of the clay. This is an outlier of a clay bed which, with its overlying gravel, can be traced at nearly the same level all across the area from Henbury to Marton. Between Marton and Gawsworth the gravel forms an extensive terrace.

This and other terraces at various elevations are clearly water levels of Glacial age and may have been formed in somewhat the same fashion as those described by Prof. J. Geikie in the Clyde basin (*Great Ice Age*, p. 175); viz., in a lake bounded by ice on one side and by rising ground on the other. But there is no certain trace of ice action in the clays, and so far as the evidence goes they might have been laid down in a lake which covered the greater part of the Cheshire plain, the successive terraces being different stages in the retreat of the waters. The various little streams which intersect the drift in this part of the area usually have remnants of sand and gravel terraces along their banks, which can be traced down their courses and connect with the lake terraces on the more open ground. These streams take their rise in the more elevated part of the drift, so that the terraces connected with them must be of later date than those formed by the Bollin. A succession of them may be seen on the sloping grounds east of Capesthorpe Park, the lowest of which claims particular notice, as it is the connecting link between the more hilly drift just described, and the flatter drift to the west. Beginning as a narrow strip of sand raised above the stream which flows through Capesthorpe Park, this terrace rapidly opens out westwards, and covers many square miles in the townships of Chelford, Withington and Kermincham. It consists of fine reddish sand of variable thickness, but generally not more than 8 or 10 feet. Eastwards, it protrudes long tongues up the little valleys near Alderley Park and Siddington, becoming more gravelly and rising in level, as it is traced up stream. Westwards, it is gradually replaced by a clay of about the same

thickness, which covers the greater part of the ground between Mr. Pocock. Peover and Goostrey, and passes into the area mapped by Mr. Howe.

Sections of the clay can be seen near Kermincham Lodge and Withington Green. It is a dense brown clay with faint traces of lamination, and containing a few striated boulders. Though it is no thicker than some of the clays in the hilly drift, it covers a far wider surface, and is comparatively little denuded. In some places it passes almost imperceptibly into sand. Elsewhere, as in the Peover Brook, near Withington Park, it may be seen with sand beds above and below. Water seems to have been the principal agent in its formation, but the Northern erratics, which it contains, show that there was an ice-front near enough to send its ice floes across the lake, and drop its stony *débris* over the muddy bottom.

The drifts of the whole area now described present a continuous story of denudation and redistribution of sediment at successively lower levels, the later stages of which were undoubtedly accompanied by glacial action, and the whole of them are subsequent to the retreat of the ice from the Pennine Hills. But whether the ice disappeared and a temperate climate supervened in the interval, the evidence collected in this area alone does not suffice to determine. That the interval was a long one may be inferred from the amount of denudation which took place. Before the deposition of the flat drifts in the west, the tiny brooks in the hilly drift cut deeper gorges, and removed more sediment than the larger streams have since accomplished in the lower ground.

RECENT DEPOSITS (CHESHIRE).

Along the Dane valley river-terraces are well developed. In Mr. Howe. the plain they are often made of sand and loam, and less frequently gravel; but on the higher ground of Bosley they are invariably composed of gravel, which is usually rather coarse, and merges gradually into the surrounding drift. These terraces occur at varying heights. Sometimes they constitute the present banks of the river, or else they lie some distance above the present river course, and rest on ledges on the steep walls of the valley. At Somerford Park a coarse river gravel lies on the edge of the plateau, fifty feet above the present alluvium. East of Mr. Wedd. Eaton Hall the highest terrace on the west side of the river can be traced for a great distance; it is unusually broad, and consists of sand and silt. The different terraces show unmistakably the formation of the present valley, which is proved to be newer than the laminated clays.

Alluvial terraces are beautifully developed along the entire course of the Dane. They are so little liable to flooding, that they are cultivated in places where the banks are high. Nearly all the streams have narrow fringes of alluvium, while many of the shallow depressions in the drift have their bottoms filled with like material.

Mr. Gibson.

Mr. Gibson observes the curious fact that these hollows and the tributary streamlets of the Dane and Wheelock rivers, converge towards the salt-bearing regions of Middlewich and Wheelock; showing that, unless the phenomena are accidental, the brine pumping has not initiated, but only assisted, the surface sinking.

Peat has accumulated in the hollows formed in both clay and sand, and has given rise to extensive mosses. Some of these still exist, but in many, notably Warmingham Moss, the peat has been completely cleared off.

ECONOMIC GEOLOGY.

Mr. Gibson.

In the Cheshire district the absence of good road-metal is a serious inconvenience. The main roads are repaired with material brought from Penmaenmawr, while for second-class roads the Crowstones of the Lower Carboniferous series to the east are frequently used.

The drift clays are extensively used for brickmaking, round Crewe, and to the north of Congleton, and to some extent round Sandbach and Holmes Chapel. The sands yield building sand.

Taken generally the clays are devoted to pasture, the sands to tillage. Crops in the sand area, suffer more from drought than those composed of clay. In the latter, the numerous ponds, chiefly of artificial origin, are of much service, for though shallow, few dry up, and many show only a small diminution in the volume of water. In a few instances, where a thin capping of clay overlies sand, the crops suffer little, as the clay prevents evaporation.

The main water supply of the district is obtained from the sands. It is however insufficient, while the water is hard, and liable to contamination. Sandbach and Holmes Chapel obtain their supplies from this source, but Crewe town is supplied from the boring in the Trias near Whitmore Station.

In North Staffordshire the gritstones of the Third and Fourth Grits have been largely used for building, and for the stone fencing of the district. The Fifth Grit of Heaton has also been quarried; while the lower sandstones of Lask Edge and Brown Edge are used for road material. The black shales of the Lower Carboniferous, and the Boulder-clay on the west of Lask Edge are used for brickmaking. A water supply for local purposes is obtained from the drift-sand.

2. SOUTHERN DISTRICT.—DEVON AND CORNWALL.

Mr. Clement Reid, F.R.S., District Geologist.

Mr. W. A. E. Ussher

Mr. J. B. Hill

Mr. E. E. L. Dixon

} Geologists.

ORDOVICIAN AND SILURIAN.

Mr. Reid.

Though the year's work has not led to the discovery of palaeontological evidence proving the Silurian age of any of the

killas in West Cornwall, yet as the mapping advances the succession of the rocks becomes more clear, and the probability of the Silurian date of extensive tracts becomes greater. It will be remembered that in former *Summaries* Mr. J. B. Hill divided the older rocks into four series, the oldest of which has long been known to yield Ordovician fossils. Above these Veryan beds come in succession the Portscatho slates, the Falmouth slates, and the Mylor series. Another lithological division, which continues the upward succession northwards may now be added, and may be termed the Hayle sandstone. It consists of thin-bedded, coarse, more or less felspathic sandstone, alternating with fine-grained black slate or shale, which latter resembles in character the shales of the Mylor series below. These four divisions, lying above the Ordovician, are provisionally referred to the Silurian, and it is hoped that the work of the coming season may enable us to show definitely the relation of the highest member to the fossiliferous Devonian of North Cornwall.

As the geological structure of West Cornwall is very obscure, it will be necessary to refer in more detail to the evidence on which this order of succession is founded; for, at first sight, the new division appears to pass under, not over, the Mylor series, and that view was taken by De la Beche in 1839.* Before discussing this matter, however, reference may be made to the newly mapped Silurian areas which were examined during the past year. The most convenient mode of doing this will be to commence with the oldest rocks, which occur in the area east of Falmouth, and work westward and northward to the newest division which has yet been mapped on the north coast.

The examination of the Gorran Haven coast sections by Mr. J. B. Hill has proved the further north-easterly extension of the Veryan series as far as that locality. It is interesting to note that the pillow lavas of Mullion Island were found at Gorran Haven on a similar geological horizon associated with limestones and quartzite. Further, although these pillow lavas had not been previously observed at this locality, Mr. Howard Fox† had discovered radiolarian beds in their immediate neighbourhood, still further linking them with the Mullion Island rocks. Although the Gorran Haven rocks have suffered much mechanical deformation and are in part converted into crush conglomerates, their characteristic appearance in the field is still preserved, and their identity is still further confirmed by microscopic sections. Besides their occurrence in these two localities, pebbles of this rock are common in the microscopic slides of the conglomerate at Nare Point, intermediate between Mullion and Gorran. They occur, therefore, along a line nearly 30 miles in extent, and their occurrence amongst the fossiliferous rocks of Gorran suggests that their age may be Arenig, corresponding to the age of precisely similar rocks occurring at Ballantrae on the coast of

* *Report on the Geology of Cornwall, &c.*, p. 100.

† A paper on "The Radiolarian Cherts of Cornwall." *Trans. Royal Geol. Soc. Cornwall*, vol. xii., 1896.

Mr. Hill.

Ayr, which Mr. Hill had the opportunity of examining in September. Their resemblance in these two areas, separated by a distance of 350 miles, is so remarkable that it is scarcely possible to distinguish them, whether we consider their mineralogical character, their unique appearance in the field, or the rocks with which they are immediately associated. The rocks of Mullion Island have mainly escaped metamorphism on account of the protection afforded by the massive rocks of the Lizard region, which have preserved them from the effects of the earth stresses from the south-east.

The Nare Point conglomerate which separates the Veryan and Portscatho series has been referred to by Mr. Hill, in a former report,* as the possible line of demarcation between the Upper and Lower Silurian. It contains fragments of pillow lava as well as of the quartzite; and as the boulders of the latter were in the condition of quartzite at the time of their deposition, the break indicated by this conglomerate probably represents a protracted interval. The conglomerate also contains foliated igneous rocks, some of which have certainly been derived from the Lizard area, so that we have in Cornwall at least two periods of metamorphism, one of which is prior to the formation of the conglomerate, and its included pebbles of pillow lava, and one later. Of the age of the former we have no evidence, except that it must be pre-Arenig, while the latter is posterior to the Culin measures.

The mapping has been restricted mainly to the Portscatho, Falmouth, and Mylor series, proving the further extension of these divisions, which are provisionally regarded as Silurian. The lithological characters of these divisions have been described in former reports. While folding is everywhere apparent, the bedding can usually be detected, as well as the cleavage. The hade of the cleavage is S.S.E., and it crosses the strike of the bedding somewhat obliquely. Judging from the data furnished by the country between Truro and Gerrans Bay, there are grounds for believing that the stresses which have folded and cleaved the slates proceeded from S.S.E. to N.N.W.

Mr. Reid.

The Mylor slates have now been traced westward and northward to Land's End and St. Ives Bay. Over the greater part of this area they retain a very uniform character, except for the variations caused by contact metamorphism. They consist mainly of soft shales or slates, black or dark-coloured when broken across, but more or less silvery on the surface of the laminae. In places they alternate with very fine-grained sandy silts, but thus far they have shown no indication of contemporaneous volcanic activity, though intruded sills of greenstone are not uncommon.

Throughout this area the strike of the axis of the sharp folds runs about N.E. and S.W.; but as the limbs of the folds are nearly parallel, and are vertical or have often a high southerly

* See *Summary of Progress* for 1899, p. 95, and *Trans. Royal Geol. Soc. Cornwall*, vol. xii., Part 6, 1901.

dip, it is not easy to make sure of the true succession. In order Mr. Reid. to ascertain which was top and which bottom in the Mylor slates, the junctions with the sheets of greenstone were examined; but it was found that in every case in which the relations could be made out the greenstones were true sills, with contact metamorphism above and below. As fossils are absent, the only other way of deciding the question lay in working out the geology in such a way as to distinguish the general structure from the sharp plication above alluded to.

The sills of greenstone round the Land's End granite give a valuable clue. They are so thick and massive that they have resisted the plication, though they are often much sheared and full of small thrust-planes. Everywhere these sills dip away from the granite at an angle which apparently does not differ greatly from the slope of the granite surface below. Further, in the neighbourhood of Penzance and Newlyn one thick sill (at least 80 feet thick) caps a series of hills in such a way as to show that it, and the associated slates, though disturbed are not overturned. Next, various slight indications suggest that the thick sills on the north coast and the sill which caps the hill near St. Erth may be on nearly the same horizon, even if they are not parts of the same sheet isolated by denudation. If this evidence goes for anything, and the sills keep approximately to the same horizon in the Mylor slates, we are apparently dealing with a mass of slate of only moderate thickness, folded and constantly repeated in small anticlines and synclines, and having probably a slight general dip towards the north. This view seems to be borne out by the similarity of the killas at Penzance and St. Ives, and its striking uniformity over the wide area between Ludgvan and Gwinear.

On tracing the killas eastward from Carbis Bay along the coast, however, its character alters somewhat, and after passing a thin greenstone sill of different appearance, we come to lighter-coloured killas, sometimes banded with green, and containing a larger proportion of fine silty sand. A pit near the western edge of the West Cornwall Golf-links shows sheared, coarse-grained, soft, highly-felspathic sandstone, with few or no grains of quartz sand. These soft, felspathic beds have been taken as the top of the Mylor slates, though they might equally well have been considered as the base of the hard Hayle sandstones which come on immediately above. Unfortunately the cliff face, where the junction should be seen, is now smothered with dune sand, and nearer the Hayle River the cliff is entirely composed of alternations of sandstone and shale. The boundary strikes southward to Lelant, then crosses the river near Hayle—unfortunately not showing clearly in the low river-bank. Next it passes through the overgrown railway-cutting south of Hayle, one end of this cutting being in dark slate, the other in light-coloured shaley sandstone. Then, following the normal strike, the boundary passes under the valley deposits north-eastward to Phillack, a good section of the felspathic top of the Mylor slates being

Mr. Reid.

visible in a new road-cutting at Bodriggy, between Hayle and Copperhouse. Excellent sections of the sandstone are seen in Black Cliff, and also in the old quarries and river-bluffs around Hayle Harbour. East of Phillack the boundary turns sharply northward, through the Towans to the coast, being readily traceable across the dunes by the mine-tips. East of Godrevy the Hayle sandstone reappears with the normal east-north-east strike, though much folded. No trace of igneous rocks, either contemporaneous or intrusive, has yet been found in the sandstone; and though careful search was made, no fossils could be discovered. Even the worm-tracks and borings, and the so-called fucoids, so often occurring in Palæozoic sandstones, appear to be absent.

The junction of the Mylor slate and the Hayle sandstone is described in some detail, for the curvature of the strike yields the best evidence for the true order of succession. The normal strike of west Cornwall is north-east and south-west, but the uplift caused by the intrusion of the granite of the Land's End has everywhere caused the killas and its interbedded sills to dip away from the granite mass. This uptilt, at right angles to the strike, must necessarily divert the strike at Lelant, where the influence of the granite begins to be felt, towards the north, if the Mylor slate underlies the Hayle sandstone; but it would be diverted towards the south if the Hayle sandstone were the older of the two. As a matter of fact the diversion of strike is to the north. North-east of Hayle there is another northward diversion of the strike, apparently unaccounted for by any granite intrusion. But here, also, the diversion seems to be caused by a granite intrusion; for Mr. Dixon has discovered between Gwinear and Gwithian a metamorphic area, which seems to point to a buried boss of granite not far below. No doubt the true junction of the Hayle and Mylor series should be drawn as a sharp zig-zag line; but not being able to trace these minute details inland, we can only follow the general strike, the variations of which bring out thus clearly the true succession.

The greenstone sills which form so marked a feature in the Mylor slates of west Cornwall, have now been mapped throughout the country west of Camborne. The rocks, however, vary so much in original lithological character, and the superimposed shearing and contact metamorphism have caused so great changes, that it seems advisable to defer any fuller description of these rocks for a future *Summary*, when the petrological work will be further advanced.

GRANITE.

Though the granites of west Cornwall, like those of Devon, are probably of late Carboniferous date, yet as those examined last season are everywhere in contact with the Mylor slates, it will be convenient at this point to deal with them and with the metamorphism they cause. Here, also, the petrological evidence

will be left for a future report, the field evidence only being Mr. Reid. mentioned in any detail.

The general character of the Land's End granite and the character of its intrusive junction with the killas are so well known that it is needless to repeat the description.* A few points of interest noticed in the course of the new survey are, however, worthy of remark. In the first place it has been found that the Land's End mass is not all of one age or type, but includes an area of about seven square miles of a fine-grained granite of later date, which extends from Gulval Downs nearly to Zennor on the north, and from Amalebrea to Carnaquidden on the west. This granite is so fine-grained that it is commonly known as "whetstone" or "sandstone." Its composition is very similar to that of the coarse granite into which it is intruded. It is a buff or grey biotite granite with small (half-inch) scattered crystals of orthoclase and rarer crystals of pinite of about the same size. Its boundary is everywhere sharply defined, but there is no section showing the actual junction of the two rocks, though at its northern limit at Beagleton Downs loose blocks on the moor show numerous veins of this fine granite penetrating coarse granite of the common Land's End type. The newer granite forms undulating land, surrounded by tors or carns of the coarser type, but itself neither forms carns nor weathers into large rounded masses like those which nearly everywhere encumber the ground outside its limits. It tends to weather into small angular blocks, which are easily removed and are more convenient for building. The farmers consider the land to be of better character, but it could not be ascertained clearly whether this was due to any difference in the composition of the soil or merely to the greater convenience for working where large boulders were absent.

Much of Penzance is built of this fine-grained rock, with dressing of the ordinary coarse granite. Thus far only the buff rock near the surface has been used to any extent, but below fifteen feet the Castle on Dinas quarry shows an excellent grey stone, which ought to be of considerable value.† The Gulval Downs rock, however, does not split in the same way as the older granite, and appears never to be used for lintels or gateposts, even close to the quarries. It is used locally for road metal, and is better than the coarse granite, but not equal to the greenstone.

The Land's End granite (as distinguished from the newer Gulval Downs granite) is remarkable for showing a distinct but irregular bedding structure, which seems to be approximately parallel to the granite surface where the granite passes beneath the killas. This bedding is very conspicuous on the weathered carns or in the cliffs. It is apparently due to the orientation of the large felspar crystals, which, during the movements of the molten rock, have tended to arrange themselves parallel to the surface past which they flowed. The structure cannot well be

* See *Summary of Progress* for 1899, p. 87.

† See also De la Beche, *Report*, pp. 161, 494.

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illustrated by hand specimens, though very noticeable in the field, for it is only an orientation of most of the crystals in one direction, not of all of them.

A short distance from the margin, usually less than half a mile away, this bedding, instead of dipping at high angles, becomes almost horizontal, suggesting that the granite overhead had formerly possessed a nearly level roof of killas. On applying this test to parts of the cliff where no killas now fringes the granite, so many places were discovered where the high outward dip was strongly marked as to leave little doubt that the present coast line corresponds very nearly with the original limit of the Land's End granite.

If the granite originally formed so flat a dome, the question naturally arises, What is its contour where hidden by killas? This question cannot yet be satisfactorily answered; but enough has been learnt to show that it often plunges beneath the stratified rocks at an angle of about 45° , though in other cases the angle is only 15° or 20° . Corresponding with the steeper hade, we find a metamorphic aureole fully three-quarters of a mile wide; but where the killas and greenstone transgress over the granite, as at Tremethick, near Penzance, the aureole widens enormously. The boundary of the metamorphic area here instead of sweeping round the bay in the granite, cuts across, suggesting that the whole area around Penzance is underlaid by granite at no great depth.

A metamorphic aureole, three-quarters of a mile wide, with a dip of the granite at 45° , would give a thickness of the aureole, measured at right angles to the cooling surface, of nearly 2,800 feet, and a depth to the granite at the outer limit of metamorphism of 4,000 feet. We do not yet know, however, to what depth this dip of 45° is continued, though in the Levant Mine a dip of nearly that amount has been followed to 1,500 feet below the sea-level, with no sign of any flattening. There, unfortunately, the width of the aureole cannot be measured, as its outer margin is beneath the sea.

Mr. Hill.

The aureole of metamorphism encircling the Carn Menelez granite has been studied by Mr. Hill so far as the unsatisfactory nature of the ground would permit. The alteration of the innermost zone, extending to 250 yards from the granite, is so marked that little difficulty was experienced in spite of the lack of good sections. Beyond that zone, however, the evidence of its extension is partial in character. The mineral alteration of the inner zone is more or less complete, Andalusite, Muscovite and Biotite being extensively developed. In the outer fringe the secondary micas are often difficult to distinguish from original constituents, while Andalusite is altogether absent, the hornfels, where it exists, being likewise confined to the inner zone, so that beyond that limit the occurrence of spotted slate is the sole evidence of contact metamorphism, and this is so partial in its distribution that the demarcation of the outer limit of alteration with any attempt at accuracy is impossible. With these "spots," tiny elongated needles, which may possibly be referred to Chiastolite, have been

observed a thousand yards distant from the granite. Speaking Mr. Hill. generally, the aureole of metamorphism is about half a geographical mile in width (1,000 yards), but at Penryn Creek the spotted slates form a loop, the outer margin of which is two miles from the nearest visible granite, notwithstanding that the loop is free from elvan dykes. Moreover, the great elvan region which abuts against the granite at Gwennap contains large areas of spotted slate, which, although the spotting is generally of a more minute character than is found bordering the granite mass, it is obviously impossible to differentiate from the other. Spotting has also been occasionally observed in the vicinity of isolated elvan dykes. For the reasons above stated, it will be apparent that an engraved line on the map, to mark the limit of contact alteration in this area, would present such an inaccurate interpretation of an important petrological problem that its omission would be less misleading than its insertion.

This question of the underground contour of the granite surface is an important one for the miner, for the occurrence of certain ores, especially tin, is known to be intimately connected with the proximity of the granite. It is interesting therefore to find, as already mentioned, that an isolated metamorphic area has been discovered north of Gwinear by Mr. Dixon, and another around Leedstown. These seem to connect the granite district of Land's End with that of Camborne; but as we have not yet sufficient data for calculating the thickness of the metamorphic aureole, measured at right-angles to the cooling granite surface, we are unable yet to calculate the depth of the granite in metamorphic areas in which no granite is seen. Besides this, the width of the aureole is not the same round the different granite masses; and this variation seems to be due not merely to variations in the hade of the granite surface, but to the different intensity of the metamorphism. The killas close to the Land's End granite, for instance, is intensely altered into knotted hornfels, and the least width of the aureole, measured at the surface, is over half a mile. The smaller mass of the Godolphin granite causes less alteration, and gives a least width of aureole of about a quarter this amount. In striking accordance with this difference, is the strongly developed chilled edge of the Godolphin granite, contrasted with the very slight chilling noticeable round the Land's End mass. It is hoped that further light may be thrown on this question when the numerous mine-plans have been examined and the relation of the ores to the granite surface has been more thoroughly worked out.

The Carn Menezes granite, which extends from Penryn to Camborne, was partly described by Mr. Hill last year.* Further examination of the jointing, orientation of the crystals and grain in this granite, shows that over the district generally the orientation is so feeble that it would often escape observation if not specially sought for. Moreover, although there is a general uniformity in the direction of orientation it is by no means constant,

* *Summary of Progress for 1900*, p. 107.

Mr. Hill.

and if examination were confined to a limited number of sections the results obtained might be misleading. At Kennal Vale, however, these phenomena are carried a step further, and the parallelism is so marked that it could not fail to be detected by the most cursory examination. It approaches a definite structure, so much so that the orientation is no longer the feeble approach to crystalline arrangement confined to the attempt at parallelism of a sufficient number of the elongated minerals to ensure a grain; but there are definite visible planes set up in the rock which dip steeply towards the margin of the granite, while the rock in places is so foliated that its schistose character can be detected in a hand specimen. The foliation of the granite at Kennal Vale agrees in its trend and general hade with the corresponding planes in the slates which flank its margin.

Following the granite boundary $1\frac{1}{2}$ miles further in a S.S.E. direction, we find at Treluswell, near Penryn, two foliated granitic sills flanking the granite about 30 yards distant from its margin. Their foliation planes correspond with the cleavage planes of the slate between which they are intercalated. Microscopic examination (3364) shows them to be granite and to be allied to that rock rather than to the elvan dykes, with which their mode of occurrence would otherwise suggest their correlation. Their N.N.W. direction, moreover, parallel to the granite boundary is nearly at right angles to the trend of the elvan dykes of the district. The evidence suggests their modification by pressure before final consolidation. There is unfortunately no available section of the granite mass adjoining, so that the nature of its margin at this locality cannot be investigated. The foliation of the granite sills agrees with the foliation of the granite at Kennal Vale, and both correspond in direction to similar planes in the adjoining slates. It has been pointed out that the deformation of the slates is the result of lateral movements acting from S.S.E. to N.N.W. It will be immediately seen that this direction agrees with one of the orientation planes which is common to the whole of the granite—further it corresponds with the foliation of the granite at Kennal Vale and of the granitic sills at Treluswell. We have strong reasons therefore for the assumption that the granite irruptions and the earth movements are not only closely related but that the movements had not ceased to operate before the final solidification of the granite.

Mr. Reid.

In the Land's End and Godolphin granite masses no evidence has been found of the foliation or schistosity such as is described by Mr. Hill as occurring in the Carn Menezes granite. There is fluxion structure towards the margin; but the fluxion is parallel to the curved cooling surface, not parallel to the cleavage or other structural planes in the killas. The only sign of contemporaneous or subsequent movement that could be found, besides small faults, is a jointing approximately parallel with the strike of the contortions in the killas. Fractures along planes of weakness in sedimentary rocks, must, however, tend to extend across intruded crystalline masses, and the subsequent intrusion of the elvans along these particular planes seems to show that they did so in West Cornwall.

ELVANS.

The mapping of the elvan dykes in West Cornwall is giving a great deal of trouble, for they are so abundant in most of the mining districts that it is important to ascertain what relation they bear to the metalliferous lodes. These dykes with few exceptions rise along the line of strike of the folds in the killas, which also happens nearly to correspond with the strike of the cleavage. They seem to be intruded along planes of weakness, and are probably connected with granitic masses below; they do not radiate from the granite bosses seen at the surface. In lithological character they vary considerably, though a common type of elvan somewhat resembles the fine-grained granite of Gulval Downs. It cannot yet be proved, however, that any of these dykes are contemporaneous with this granite. Some of them penetrate the older granite, but none can be found near the newer mass, which, however, appears in an area in which no elvans occur. North-west of a line drawn from Whitesand Bay through Hayle north-eastward, elvans seem to be absent.

Mr. Reid
and
Mr. Dixon.

Though several of the elvans are schorlaceous and metalliferous, this impregnation seems to be a metamorphic change belonging to a late stage. Two series of intersecting elvans, near Rosewarne and Gwincar, have been examined by Mr. Dixon. He finds that an older series of non-metalliferous quartz-felsites, having a fairly constant north-east and south-west strike and northerly hade, is cut by a newer series of almost non-porphyrific felsitic dykes of somewhat different character, having a more westerly strike, and in some cases, at least, having a hade to the south. These newer dykes are schorlaceous and metalliferous, or are closely associated with metalliferous lodes in the killas; the older dykes, on the other hand, appear only to contain ore where they come within the influence of the newer group.

The elvan dykes are very unevenly distributed over the area north of Falmouth, examined by Mr. Hill. They attain their greatest development in a belt of country extending from the granite margin at Gwennap through Perranarworthal to Kea, diminishing in extent towards Truro—beyond which place in the ground mapped as far to the north-east as Probus they have not been noticed. Similarly in the region lying to the south-east of Gwennap, except for a small group in the neighbourhood of Penryn, their occurrence is insignificant. It may be noted that the belt of elvans between Gwennap and Kea marks the beginning of the great metalliferous region extending from Gwennap to Camborne. In this elvan belt, the quantity of vein quartz is so enormous that the soil is materially impoverished, and over a great portion the slates contain knots, although far removed from the nearest visible granite—the knotting, however, is of a more minute type than that displayed in the aureole of metamorphism which flanks the granite. The Gwennap group of elvans has not yet been traced as far as the granite margin, but in the district lying to the south-east one elvan only has been traced within the granite. It has been followed for over a mile from Towntanna

Mr. Hill.

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to Trevaies. In size, the elvans range from a few feet to many yards in thickness. A dyke, however, of abnormal dimensions has been traced following an east and west course through Gwennap, and attaining a width of 150 to 200 yards. This dyke has been followed for two miles, and its westerly extension towards the granite margin has not yet been reached. The general direction of the elvans is north-easterly to east-north-easterly. Their hade is usually very steep, and so far as observations have gone they appear to incline more frequently to the north-west than to the south-east. They exhibit, however, much variation in this respect, and sometimes lie nearly flat. They vary considerably in texture, from extremely fine types to examples so coarse that their porphyritic feldspars may attain a size of $\frac{3}{4}$ inch. The feldspars consist of both orthoclase and plagioclase. Quartz occurs in blebs, and often with a bipyramidal habit, crystals sometimes exceeding $\frac{1}{4}$ inch in size. White mica is more abundant than biotite, occurring not only as an original constituent but as a decomposition product of the feldspars. A characteristic feature of the elvans is the tendency for the white mica to assume a radiating or plumose habit, and in the matrix of the rock to combine with the feldspar in forming a pegmatitic structure. This granophyric habit in connection with the white mica is general amongst the elvans. It is not confined to the micro-pegmatitic type, but pseudo-spherulitic structures are also noticed. Feldspar and quartz occur as crystals of an earlier generation than the matrix. Not only are the crystals penetrated by the ground mass, but there is a tendency for silica to aggregate round the quartz grains. The feldspar shows a marked tendency to decompose, much white mica being developed as an alteration product. In some instances the plagioclase may be noticed altered to white micaceous substance, while the potash feldspars are little decomposed. The decomposition of the feldspars proceeds often from the central core, and selvage edges of shrinkage have been observed bounding the feldspar crystals.

CHINA STONE.

Mr. Reid.

The china stone is granite altered, and with its feldspar kaolinised *in situ*, apparently by the solfataric action of fluoric and boracic vapours. This decomposed granite occurs, as is well known, in enormous irregular masses or pipes which seem to have an indefinite downward extension—at least they show no sign of narrowing at the greatest depth to which they have been worked. The distribution of these masses is peculiar, and strongly supports the view that they represent channels along which the vapours escaped. There is one mass in the middle of the Land's End granite about midway between Penzance and Cape Cornwall; there is another mass in the centre of the area of newer granite now first recognised. A third mass occurs about the middle of the Godolphin granite. In each case a vent seems to have occurred in the highest part of the granite dome, and only one such vent has been discovered in each boss. Whether this rule will hold good for other districts remains to be seen.

DEVONIAN.

Mr. Ussher has been engaged on the Devonian rocks of east Cornwall, completing the survey of the new series map sheet 348, and carrying the work westward into the adjoining sheet 347. The strata mapped embrace all the Lower Devonian divisions, Middle Devonian slates and slaty mudstones, and in the neighbourhood of Quethiock slates and schalsteins which may belong to the Upper or Middle Devonian, or wholly to the former group. The Lower Devonian rocks are the westerly continuation of those of the Looe area. Up to 1901 the Lower Devonian succession had never been satisfactorily established, an unbroken sequence of the constituent subdivisions having been nowhere encountered.

A few days devoted to the comparison of coast sections has greatly facilitated field work during the last two months of the year, and coupled with the identification by the palæontologist of the fossils collected in 1900 in the Torquay promontory, has yielded more satisfactory results than have heretofore been obtained. These results have a direct bearing on every Lower Devonian district in South Devon, and will, it is confidently expected, much facilitate future work in Cornwall.

The year's work in the field, and in reviewing the evidence, tends to place the Dartmouth slates at the base of the Lower Devonian. These slates often exhibit pronounced green and purple tints, and delicately blended mottling of purple and pale purple and grey; but these characteristic colours often give place to buff and drab tints, and grey, and even blackish slates may be found. The slates are often siliceous; they present glossy surfaces and contain beds of very hard grit and arenaceous rocks. The hard grits or quartzites, both in the area east of Fowey, and in the Kingswear promontory, locally result from the amalgamation or welding together of siliceous shales or slates. On the whole, the aspect of Dartmouth slate sections suggests a coincidence between bedding and cleavage; but when attempts to procure cleavage-dips are made, the angles of schistosity are found to vary, and occasionally hard grits are seen to cut off the planes of schistosity in the slates. From many indications of local irregularities, there can be little doubt that the slates of this series, where they seem to present a continuous succession, are constantly repeated by sharp folds which have been broken and sheared out. In the coast west of Polperro and south of Lansallos, the association of grits in the slates is the same as that displayed on the Revelstoke coast. Many contortions are exhibited by them, including the vertically zigzagged bedding so frequent in the Devonian rocks of south Devon and east Cornwall. These slates have now been traced from the Kingswear promontory westward to the Fowey estuary. In this extension their persistence is only broken near East Allington, in the Kingsbridge area.* The problem of the geological

* See Map in Rep. of Easter Excursion, 1901, *Proc. Geol. Assoc.*, vol. xvii., p. 121.

Ussher. structure of Cornwall, south and west of a line between Fowey and Watergate Bay, is precisely similar to that of the Kingsbridge and Torcross area, in both cases we have partly fossiliferous rocks on the south of the Dartmouth slates. What are their relations to the Dartmouth slates: are they newer or older? If the former these slates must be regarded as an anticlinal; if the latter, as an outcrop, any impersistence in which can only be explained by fault or change in character.

In the *Summary of Progress* for 1900, pp. 60, 61, reference is made to fossils collected in the Torquay promontory, the Kingsbridge area, and the Looe area; the results of the examination, re-examination and comparison of these fossils were received from the Palæontological Department in January, 1901, together with a list of fossils collected by Mr. Upfield Green, from Looe and Fowey.

From these lists the following fossils may be taken as characterizing the Looe and Fowey fauna:—

Orthotetes hipparionyx	Rhynchonella pengelliana (scarce)
Spirifer primævus	Pleurodictyum problematicum
Streptorhynchus gigas	

In the badly preserved fossils of the Kingsbridge area (Ringmore beds) all the above except *Rhynchonella pengelliana*, have been recognized as far as the condition of the crushed casts and impressions would permit. In the Torquay promontory (New Drive) *Orthotetes hipparionyx* occurs in a fossiliferous horizon containing numerous fragments of spined *Homalonotus* and casts of *Strophomena latecosta* (also in the New Cut and on Oxlea Hill). *Spirifer primævus* was found in the Meadfoot beds near Hopes Nose with a *Homalonotus* resembling *H. Ræmeri*, *Strophomena rhomboidalis*, *Zaphrentidæ*, &c. *Rhynchonella pengelliana* was doubtfully identified by Mr. Etheridge among fossils collected by Champernowne from the New Cut. Davidson thought that he recognised it amongst fossils collected by Mr. Whidborne in the Saltern Cove railway cutting. *Streptorhynchus gigas* is given in Tawney's lists amongst fossils collected west of Hopes Nose Raised Beach; presumably from the uppermost grits of the Lower Devonian. *Pleurodictyum problematicum* is common in the Torquay promontory, and confined to no special horizon. As the Lower Devonian rocks of Torquay and Paignton are all above the Dartmouth slates, which do not appear at the surface, and palæontological evidence is all in favour of the correlation of the fossiliferous strata with those of the Looe and Fowey area, which unquestionably are represented in the Kingsbridge area, it follows that the Dartmouth slates are the lowest member of the Devonian of South Devon and of Cornwall as far west as the Fowey estuary.

The Torquay promontory is, perhaps, the worst tract in the south-west of England to obtain evidence of the actual sequence of the Lower Devonian rocks, owing to faults and contortion. The coast section south of Brixham has not yet been actually

compared with the Plymouth and East Cornwall sections, and Mr. Ussher. the comparison of the Ringmore section is not yet completed. In both these sections the Dartmouth slates appear to be in contact with dark slates, which in the Ringmore section pass up into the fossiliferous beds.

In the Plymouth section the practically unfossiliferous Staddon grits are well developed; they rest on grey slates with hard grit beds and bands, presenting at Boveysand the same relation of pronounced cleavage broken by bedding planes that is so pronounced in the grey slaty siliceous rocks forming the coast line between Fowey and Pencarrow Head. The grey slates succeeding these beds in the Plymouth section contain *Zaphrentidae*, and in parts of the section the bending or distortion of the cleavage planes at intervals is the only indication of bedding. At the south end of Crownhill Bay the slates become calcareous and pass into red very fossiliferous decomposed friable slaty beds crossed by limestone bands containing monticuliporoid corals, &c., identical in all respects with the red and grey limestones associated with the Looe beds at East Looe beach and at Millendreath. These beds are associated with hard fine-grained grits of the same type as those at Beesands, south of Torcross, and they are faulted against the Dartmouth slates at Andurn Point. This faulted north boundary of the Dartmouth slates extends eastward to Modbury.

Turning to Tregantle on the Cornwall coast, we find a great development of the fossiliferous beds identical in every respect with those of the Plymouth section, which when traced inland are seen to contain the same grit types as at Looe and in the New Cut near Torquay. Between these beds and the purple and green mottled Dartmouth slates, on the east and on the west, grey and dark grey slates, with grit beds and arenaceous interbanding in part, form the cliffs. Traces of *Pteraspis* have been found in these slates toward Portwrinkle, so that in part they belong to the Dartmouth slate series, and form a passage into the overlying beds of the Meadfoot series. In the *Summary of Progress* for 1899, page 84, these slates are referred to, and their connection with the Bindown and Congorlan quartzites is correctly foreshadowed. During the latter part of the year 1901, general boundaries were drawn in the area between Lanreath and Polperro separating the grey slates and grits from the variegated Dartmouth slates on the one hand, and from the more or less fossiliferous slates and grits which represent the Looe beds on the other. The latter is a purely tentative line and could not be continued eastward, but there are indications of the development of the local characters of this intermediate series westward. Just north of Lanreath the Dartmouth slates appear in an impersistent mass or masses cut off by a fault on the north, and bounded by dark slates on the south. Here, therefore, as at Bindown and Congorlan the Dartmouth slates appear on the north of the fossiliferous Looe rocks, in which, although there are evidences of crinoids and occasional fossil traces (in slates of Ringmore types), few markedly

Mr. Ussher. fossiliferous beds were encountered, probably owing to the absence of good exposures. The grey slates with hard grit beds and arenaceous banding are, however, well evidenced, both on the north and south of the Dartmouth slates, which they separate from the fossiliferous grits and slates of Pencarrow Head, rightly correlated by De la Beche with the fossiliferous rocks of Looe. The Dartmouth slates would therefore appear to form an anticlinal $1\frac{1}{2}$ miles in breadth, bounded by practically unfossiliferous slates, grits, sandstones, and interbanded argillaceous and arenaceous rocks, which for convenience of reference may be provisionally termed Lower Meadfoot beds. An interesting section of these beds is afforded by the south shore of Point Pill Creek, where they are faulted against purple and green Dartmouth slates on the north. In this section grey and dull greenish-grey slates, variegated with buff and straw-coloured tints, and in places associated with beds of tough buff silty rock, and occasionally of hard grit, strongly resemble the variegated slates and arenaceous rock of Mr. Hill's Falmouth series. A faulted development of buff or silty rocks of a type common in the Pelynt district occurs in them. Grit beds here and there show sharp folding, and in one place a mass of tough dense grey grit suggests the local development of beds similar to those of Bindown and Congorlan. Near Brawn Point blue and straw-coloured slates exhibit cleavage planes dipping at a low angle with small wavy undulations due to the intersection of slightly harder silty intercalations. Near this, fossiliferous beds come on which include thick bedded yellow-brown arenaceous rocks, in part very similar (honeycombed with distorted fossil cavities) to the fossiliferous beds of the Tregantle and Plymouth coast sections, and on the same line of strike with the fossiliferous beds of Pencarrow Head.

It is important to note that an argillo-arenaceous or silty character, similar to that displayed in the Point Mill Creek section, is frequent in the Looe area, and in the absence of fossils this deterioration of grits, belonging to the fossiliferous series, cannot be distinguished from similar associations in the Lower Meadfoot beds. The Staddon grits exhibit a similar deterioration traced westward, being locally an argillo-arenaceous series in which more or less silty mudstones predominate over the harder grit beds. The assimilation of different horizons in the Lower Devonian, through the assumption of practically identical lithological characters, renders the mapping extremely difficult and most unsatisfactory where faults have to be drawn, as is the case with a west-south-west fault cutting out the Dartmouth slates of Bindown and Congorlan, which is shifted by an exceedingly indefinite cross fault, and in further prolongation forms the north boundary of the patch of Dartmouth slates north of Lanreath.

CARBONIFEROUS.

Mr. Teall's microscopic examination of the Wearde grauwacke and similar beds at Forder Lake, both near Saltash, proves that

these rocks are made up of quartz, felspar, fragments of felsitic and (locally) andesitic igneous rocks. His examination of Culm grits from near the River Tavy south of Abbey Bridge, Tavistock, entirely favours the correlation of the Wearde Efford rocks with the Culm grits (base of Middle Culm Measures), as suggested by Mr. Ussher.* The conditions under which they were formed are explained in the paper here quoted.

During 1901 exceptional opportunities for observing these beds were afforded by the cutting of a new road south of Lower Compton village, and in a deep section driven northward into the hill on which they are best developed. The grits, in even beds separated by masses of dark shaly slate, vary in grain and hardness, and in places present the character of a fine breccia or tuff containing numerous small pieces of shale. The excavation terminates in a mass of exceedingly hard igneous rock. In Lower Compton road the section begins with vesicular volcanic rock, succeeded by very hard even-bedded grits, with shaly intercalations and coarse and fine fragmental rock containing pieces of shale, &c.

PLIOCENE.

The survey of the Land's End district has led to the discovery of one outlier of Pliocene deposits besides that already known at St. Erth. The new outlier occurs on the ridge north of Cannon's Town, on the opposite side of the valley to the St. Erth pits, and at an elevation slightly greater (150 feet). It consists merely of the ferruginous pebbly sand or soft sandstone known as "growder," the fossiliferous clays seen in the St. Erth pit being missing. The search for Pliocene deposits has, however, resulted in the discovery of a striking feature in Cornish geology. In describing the St. Erth deposit reasons were given for thinking that the fossiliferous clay indicated a depth of water of 40 or 50 fathoms, and nothing that has since been discovered has led us to modify this view.† If this view is correct we ought to find traces of a Pliocene shore-line near the 400 foot contour, for the fossiliferous clay lies about 120 feet above the present sea-level. When the deposit was examined in 1886 no shore-line could be found in the neighbourhood, for all the country near St. Erth lies below the 400 foot contour, and shows signs of having been planed and smoothed by the sea. Out of this undulating plateau, however, rise in the distance various abrupt and more rugged hills, and the examination of the whole district has now shown that a clearly-defined ancient shore-line bounds this plane of marine denudation at a height of about 420 feet above the present sea-level.

Notwithstanding the strong presumption that the plateau was once occupied by Pliocene strata, and that the old cliff marks the

* *Proc. Somerset Arch. and Nat. Hist. Soc.*, vol. xlv., p. 50, 1900. See also *Trans. Inst. Mining Engineers*, vol. xx.

† "The Pliocene Deposits of North-Western Europe." *Nature*, vol. xxxiv., p. 341 (1886); The Pliocene Deposits of Britain, "*Memoirs of Geol. Survey*," chapter v. (1890).

Mr. Reid.

former limit of these strata, it is exceedingly doubtful whether the whole of these features were of Pliocene date. The plateau is so extensive, and is cut in such hard rocks, that it is difficult to imagine that the Pliocene sea could have levelled it. Perhaps after all it is a feature of much older date, merely cleaned up and sharpened in Pliocene times. In support of this view, we can point to the very similar plateau in Gower, described in Mr. Strahan's report (p. 49), for on that plateau have now been discovered two outliers of Trias. It is hoped that further work in Cornwall may throw light on this striking feature.

RAISED BEACHES.

Thus far no Pleistocene deposit older than the raised beach has been recognised in West Cornwall, though there are indications that the whole coast is fringed with a more ancient erratic deposit, which lies entirely beneath the present sea-level. The numerous small erratic blocks which occur in the raised beach probably belong to this older deposit; for nothing has yet been found in the newer one to suggest anything but a temperate climate, and the foreign stones in the raised beach are all sufficiently small to have been brought up during storms from a depth of 5 or 10 fathoms attached to the roots of oar-weeds. The larger blocks, so often found in dredging and trawling, do not seem to occur in the raised beaches.

The highest raised beach yet discovered in Cornwall is seen in Penlee quarry, near Newlyn, where coarse beach-shingle rests on a rocky shelf 65 feet above Ordnance datum. The old cliff and beach can be traced at about this level through Penzance, and sweeping round Mounts Bay behind the marshes. It is recognizable also at frequent intervals round the coast, as a notch and narrow steeply-sloping ledge, more or less hidden by head and talus. Everywhere it yields erratic stones, though these are especially abundant where, facing the raised beach, is found a considerable extent of shallow sea. The foreign rocks are mostly subangular Chalk-flint and Greensand-chert, like the altered rocks found in the Bagshot gravels of Devon, and pebbles of a hard purple sandstone of doubtful origin. These occur everywhere, but at Cape Cornwall was found also a single pebble of biotite-trachyte or biotite-andesite closely resembling some of the Permian volcanic rocks of Devon, though unlike anything belonging to Cornwall.

WATER SUPPLY.

Another season of deficient rainfall caused great anxiety as to the water-supply of many Cornish towns and watering-places. This question is a very difficult one to deal with, for great part of the country has been so riddled with mines that the water

drains away far more rapidly than was formerly the case. Besides Mr. Reid, this, great caution has to be used as to the source of the supply, for though the limited inland population in most of the area examined in 1901 renders it fairly easy to avoid surface contamination, yet the common occurrence of copper-salts in solution necessitates the rejection of many copious sources.

Penzance is now undertaking new works for increasing the water-supply by tapping the elvan which crosses the altered killas near Madron. These elvans are often valuable sources of water-supply in Cornwall, though in different cases they behave very differently. The porous much jointed elvan near Penzance forms a dyke in the more impervious killas, and seems to act as a channel, probably conducting a good deal of water from the granite hills above. In other cases, decomposed or kaolinised elvans form clayey dykes which dam up the water, so that its level is much higher on one side than the other.

SOILS.

The soils over parts of the Land's End district have already been alluded to, but it may be remarked that for market gardening, flower culture, and dairy farming, which are now becoming so important in Cornwall, the nature of the underlying rock and the chemical composition of the natural soil are only two of the requirements. Cornwall depends so largely on the production of vegetables and flowers earlier than, or at seasons different from, other parts of England, that aspect and shelter are even more important than soil, especially as the soil is so freely enriched and altered by heavy dressings of shell-sand and seaweed. Some of the best land for this spade culture is found where the slopes face the sun, as they do around Penzance, and at the same time have a mixed soil of greenstone and killas, lightened by a coarse, sandy wash from the granite above.

Not only is the soil greatly modified by intentional transportation of sea-sand, but it must also be changed by wind-borne dust for much greater distances than is usually thought. Last year, during gusty E.N.E. winds, at Carbis Bay, from a height of 270 feet above the sea, swirls and puffs of dust were seen to rise from the desert-like flat at the mouth of the Red River to a height of at least 240 feet. They nearly blotted out Godrevy Towans (230 feet) and Godrevy Lighthouse, and then spread in a well-defined belt across St. Ives Bay for over three miles to near St. Ives Head, which the belt must have passed.* Soils thus modified by dust and calcareous sand cover most of the rock near Hayle and Lelant.

The *granite* in the Falmouth area forms a dome-shaped table-land and supports a soil adapted for cultivation. Knolls of solid rock appear at random above the soil and on the slopes of the valleys, but apart from these rocky exposures the ground forms good arable land. The disintegration of the granite, however,

* See Reid, *Nature*, March 6, p. 414.

Mr. Reid. yields a somewhat cold soil, and crops are not so advanced as on the slate-bearing ground.

Mr. Hill. *The Portscatho series* yields a generous soil, which is considerably enhanced by the arenaceous beds, which, keeping the soil from becoming too coherent, admits of the ready passage of the surface drainage. The rocks of this division, however, are everywhere carved into deep valleys, the slopes of which are often so steep that the surface soil is washed off to the lower grounds, resulting in a hill slope comparatively barren.

The Falmouth series produces some of the richest land, and this is especially the case where the soft, sandy beds predominate. The presence of so much more iron in its chemical composition will account for its comparative superiority in this respect to the other sedimentary divisions. This division has a tendency to form lower ground, and shows no disposition to the formation of steep valleys, so that barren land within this division is exceptional.

The *Mylor Slates* in this district support a soil inferior to the other sedimentary divisions. This is largely due to the fact that it flanks the granite, the marginal portion of that mass and the adjoining slates being the metal-producing zone, so that it has been extensively veined by quartz. The quartz *débris* scattered over the ground is sometimes so great that the surface soil consists of little else, and the land is out of cultivation, while in other districts the agricultural land is considerably impoverished from this cause. Where these conditions, however, do not prevail, the soil is little inferior to that of the Portscatho or Falmouth divisions. This division has a tendency to form uplands with shallower valleys than are found in the Portscatho series.

3. SOUTH WALES DISTRICT.—GLAMORGANSHIRE AND CARMARTHENSHIRE.

Mr. Aubrey Strahan, District Geologist.

Mr. R. H. Tiddeman	}	Geologists.
Mr. B. S. N. Wilkinson		
Mr. T. C. Cantrill		
Mr. H. H. Thomas		

ORDOVICIAN ROCKS.

Mr. Strahan. The surveying of Sheet 230, which includes the North Crop of the coalfield from Ystradgynlais to Mynydd Mawr, has necessitated the mapping of some of the older rocks near Llandilo. The Ordovician Rocks enter the sheet with a strike of W. 30° S., which, however, curves westwards to nearly east and west. The movement to which this strike is due has been so energetic as not only to place the strata of a broad belt of ground in a vertical position, but to give rise to over-folding and over-thrusting. All the rocks up to the Coal Measures are involved, but the effects of the movement are manifested chiefly in the older rocks, and to a

less degree in the Carboniferous areas, though it has sufficed to Mr. Strahan. tilt the limestone and Millstone Grit at an angle of 45° , and to plicate the Coal Measures near Llandybie.

Proof has been obtained of the existence of movements of more than one age, but the dominant, and perhaps the most recent, has been that to which the present strike is due. By its direction this disturbance links itself on to those of Cribarth and the Vale of Neath. These well-marked belts of compression range about $W. 30^{\circ} S.$, and succeed one another at fairly regular intervals. Thus the Vale of Neath disturbance is followed, after an interval of seven miles, by the Cribarth disturbance. Cribarth is followed, at seven miles distance, by the Tair Carn anticline, and that anticline, both by direction and situation, is connected with the upheaved belt of Ordovician and Silurian rocks.

Of the age of this system of movements we have no direct proof, but the work has shown that it was probably not contemporaneous with the pre-Triassic east and west folds of the South Crop. Neither the Vale of Neath nor the Cribarth disturbances link themselves on to that system, either in character or direction.

It has been observed, by both Mr. Cantrill and Mr. Thomas, that the dip of the Silurian rocks is generally steeper than that of the Ordovician. Both dip to the south, but the Silurian at 70° to 80° , while the older rock dips at 45° to 60° only. If the junction were an unconformity and not faulted, this could only be accounted for on the supposition that the Ordovician strata had had a northerly dip before the Silurian rocks were deposited; but the evidence for a great fracture is so convincing that we may adopt the explanation that the difference in inclination is due to two portions of a great S-shaped (sigmoidal) curve having been faulted into juxtaposition. Thus the Ordovician rocks have the angle of dip proper to the upper limb of the S; while the Silurian rocks have the steeper dip which prevails in the central limb.

The district is traversed also by some clean-cut normal faults of the N.N.W. direction. A good example of such a fault has been traced by Mr. Thomas from Bryn Martin Uchaf to the Keeper's Lodge at Llanfihangel, the shift of outcrop being as much as 100 to 150 yards in highly-inclined beds; but no case has been found of a N.N.W. fault traversing the whole of the belt of disturbance referred to above. The results of the detailed mapping are recorded by Mr. Cantrill as follows:—

The Ordovician rocks are excellently exposed in the sides of the Mr. Cantrill. River Cennen and in a railway cutting at Ffairfach. They show the following sub-divisions in descending order:—

- | | | |
|----------------------------------|---|------------------|
| 3. Flags and Limestones | } | Llandilo Beds. |
| 2. Ffairfach Grit | | |
| 1. <i>Didymograptus</i> -Shales. | | Llanvirn Beds(?) |

Mr. Cantrill
and
Mr. Thomas.

1. The *Didymograptus*-Shales* are somewhat micaceous black shales and mudstones, containing numerous *Didymograptidae* with a few *Lingule* and trilobites. Their base is nowhere seen, but the shales are probably at least 300 to 400 feet thick. They pass up into a more sandy and micaceous rock with few or no fossils. In carrying on the work westwards Mr. Thomas estimates that the unfossiliferous micaceous part of the shales is 150 feet thick, and that the graptolitic shales are exposed to a thickness of probably more than 200 feet. He finds *Didymograptus bipidus* to be the commonest form, but the classification of the beds will depend upon further identifications.

2. The Ffairfach Grit is described by Mr. Cantrill as a hard, yellowish sandstone, grey and calcareous when unweathered, and about 150 feet thick. It is found by Mr. Thomas to pass in places into a sandy limestone, apparently unfossiliferous. It is well exposed in the Ffairfach cutting and under the terrace of Golden Grove House.

3. The Flags and Limestones of the Llandilo group, as shown in the Ffairfach cutting, consist of about 150 feet of thin-bedded, dark grey sandy mudstones, overlain by 150 feet of pebbly, soft sandstones, above which, again, come dark flags and limestones, often weathered into rottenstones. The outcrop in the Cennen Valley is found by Mr. Cantrill to be two-thirds of a mile broad, which, with a dip ranging from 40° to 70°, indicates an *apparent* thickness of about 2,500 feet. The top of the flags is not seen. In reference to these rocks farther west, Mr. Thomas writes that the limestones cannot be traced far, owing to their habit of weathering into rottenstone, but that they are not so sporadic as would appear at first sight. A large mass occurs in an old quarry in Golden Grove Park. He finds in the flags and limestones an abundance of fossils, chiefly trilobites and brachiopods. Here, also, proof is obtained of a great gap between the highest seen Ordovician and the Silurian rocks, the upper Llandilo being absent in Mr. Thomas's opinion, as well as the Bala and Llandovery series.

SILURIAN ROCKS.

Llandilo.

Mr. Cantrill.

The development of hard red and grey pebbly grits (Passage Beds) forms one of the most conspicuous features in the highest Silurian rocks near and east of Llandilo. These strata form a well-marked ridge extending from Trichrug, where they are well developed, westwards towards Storm Hill, but farther west they disappear, partly through an unconformable overlap by the Old Red Sandstone, but not less by gradual attenuation in themselves. In the eastern part of their range, at Cilmaenllwyd, Mr. Cantrill finds the following descending succession:—

* This name was introduced by Messrs. Marr and Roberts. *Quart. Journ. Geol. Soc.*, vol. xli., p. 476 (1885).

Old Red Sandstone: red micaceous marls, containing *Lingulae* for about Mr. Cantrill. five or six feet above their base, passing down into

		Ft.
Passage Beds.	Tilestones: yellow, highly micaceous sandstones formerly wrought for tiles; fossiliferous; about -	150
	Trichrug Beds: red sandstones and grits and sandy marls, mostly pebbly; passing down into yellow grits at their base -	600
	<i>Grammysia</i> -beds: dark purplish-grey, flaggy sandstones, with thin seams crowded with fossils, among which <i>Grammysia</i> is very abundant; about -	180
Ludlow and Wenlock.	Greenish-buff mudstones, with thin harder seams, and below them several bands of hard yellow sandstone, one about 150 feet thick, for which the name of Lletty Grit will be convenient -	2000
	Greenish-grey mudstones - - -	-

The last-named may be assigned to the Wenlock group. In Mr. Thomas carrying on the account westwards, Mr. Thomas observes that both the Tilestones and Trichrug Beds have disappeared near Golden Grove Park, leaving the Old Red Sandstone in direct superposition upon Ludlow mudstones. In the same neighbourhood the base of the newer formation becomes conglomeratic and contains angular fragments of the underlying mudstone. Between the Ludlow and Wenlock he finds that no hard-and-fast line can be drawn. The Lletty Grit, one of the most constant of several grits which make their appearance in the middle and upper parts of the Silurian mudstones, is about 180 feet thick, and can be traced on. Sandstones are, on the whole, thicker and more abundant in the upper than in the lower part of the mudstones. Fossils abound along certain lines, not, however, in the grits. Amongst others he has obtained *Calymene Blumenbachii*, *Plucops caudatus* and other trilobites, with *Atrypa reticulata*, *Leptæna rhomboidea*, *Cyrtia exprorecta*, etc.

With respect to the junction of the Silurian and Ordovician rocks near Golden Grove, Mr. Thomas makes the following note:—

The lowest Silurian rocks are greenish-brown or buff mudstones, with thin bands of sandstone. These are of Wenlock age. They rest sometimes against Llandilo flags, sometimes against the Ffairfach Grit, and sometimes against the *Dilymograptus* shales. The junction is therefore either an unconformity of great magnitude, or a fault. But though it is exposed in four places, the base of the Silurian rocks contains no trace of conglomerate such as might have been expected in the case of a great unconformity. On the other hand, there are indications that the Silurian mudstones have been indurated near the junction, and that in both them and the Ordovician a cleavage has been developed, with traces of foliation along bedding-planes. At the back of Golden Grove the junction is laid bare by a stream for 250 yards, and here it is actually seen to be a fault, accompanied by much crushing on both sides, and signs of shearing in the neighbouring beds. The

Mr. Thomas. evidence points to its being a fault in all other parts also of the district mapped. The conclusion is in accord with Mr. Cantrill's observations. At an exposure of the junction at Troedyrhiw he finds that the Silurian rocks dip at an angle of 40° towards vertical Llandilo beds, and concludes, both from this and the absence of conglomerate, that the junction is a large fault, or perhaps a thrust.

Gower.

Mr. Strahan. Two inliers of Silurian rocks have been found this year in Gower. They had escaped notice in the original survey of South Wales, and were not known to exist until they were detected by Mr. Tiddeman. The larger of the two forms an undulating table-land on the north side of the ridge known as Cefn-y-Bryn. The Old Red Sandstone composing the ridge dips southwards, and from beneath it emerge soft, olive-coloured shales, the junction between the two being sharply defined. The inlier, though two and a half miles long, is narrow, being bounded on the north by a fault which throws down various members of the Old Red Sandstone and the Lower Limestone Shales in succession.

Mr. Tiddeman. The smaller inlier lies north-west of Penmaen Workhouse. On its east side it is bounded by a fault which crosses the anticline of Cefn-y-Bryn obliquely; but towards the south-west it is succeeded naturally by Old Red Sandstone. The shales are poorly exposed, but Mr. Tiddeman obtained fossils, which were identified by Mr. Newton as:—*Rhynchonella* (like *R. nucula*), *Bellerophon* (like *B. Murchisoni*), *Modiolopsis*?, *Chonetes* sp., crinoid ossicles, entomostraca.

OLD RED SANDSTONE.

North Crop.

Mr. Cantrill. The mapping of the Old Red Sandstone on the north side of the Coalfield has been continued by Messrs. Cantrill and Thomas. With respect to the neighbourhood of Derwydd Road and Trapp, Mr. Cantrill writes that the lowest subdivision, or red marls, is exposed in the Cennen, but that none of the conglomeratic cornstones, so frequent near Gwynfe and eastwards, are present. At Cilmaenllwyd the lowest few feet are highly micaceous and contain a few small *Lingulae*, survivors, possibly, of the Silurian fauna. Traced westwards, the basement-beds become more sandy and assume a pale-green and yellow colour. No hard-and-fast line could be drawn between these and the Tilestones of the Silurian Passage Beds, the one seeming to pass into the other. This is especially noticeable in an excellent section on the main road to Llanelly, on the west side of the Cennen Valley.

Mr. Thomas. Still farther west, however, the succession is changed. As noticed above, Mr. Thomas finds a marked overlap of the Silurian rocks by the Old Red Sandstone, accompanied by the development

of conglomerate in the base of the newer formation. A green tinge prevails at the base of the Old Red Sandstone, and one of the lowest beds is a fissile green sandstone, which has been worked as a tilestone, but which must not be confounded with the Tilestones of the Silurian Passage Beds.

The series of green and dull-red sandstones, to which Mr. Cantrill gives the name of Senni Beds, forms the lower part of the Brownstones, and has been traced continuously so far as the surveying has proceeded. The great mass of the Brownstones above repeatedly yields exposures, but whereas in the Carmarthen Fans the beds consist of innumerable alternations of sandstone with marl, farther west marls form the bulk of the subdivision. The quartz-conglomerates, also, which form the scarps of the Carmarthen Fans persist no farther west than the Clydach Valley. It thus happens that the Grey Grits, or uppermost subdivision of the Old Red Sandstone, there rest upon marls.

A little farther west, however, the Grey Grits disappear, but to the south of Trapp an olive-green sandstone with quartz-pebbles comes in at a probably lower horizon below the Lower Limestone Shales. At Llandyfan, where the rock is about 20 feet thick, and contains rolled flakes of dark shale, it is separated from the Limestone Shales by 150 feet of coarse red sandstone and red marls. North of Llandybic the upper beds of the Brownstones tend to become still more sandy, as is well shown at Cilyrychen Quarry, where the Lower Limestone Shales, with a few feet of dark green sandstone at their base, rest upon green, red and brown sandstones and marls with conglomeratic cornstones containing fossiliferous pebbles.

The disappearance of the Grey Grits has been traced by Mr. Cantrill step by step from the Carmarthen Fans, by the head of the Cennen, where they are pebbly and 15 feet thick, to Banc Wern Wgan, where they are devoid of pebbles and only 8 feet thick. Farther west they are represented by only about 6 feet of greenish-brown grit, separated from the Lower Limestone Shales by a few feet of red marls; but no obvious representative of the Grey Grits has been recognised west of Cwrt Bryn-y-Beirdd.

Gower.

In Gower the Old Red Sandstone has been found by Messrs. Tiddeman and Wilkinson to occur in the form of sharp anticlinal folds, running approximately east and west. In nearly every case, however, one limb of the anticline is replaced by a fault. The following subdivisions are recognised:—

- White quartz-grit (the Grey Grits), freely charged with pebbles of vein-quartz.
- Red ditto ditto
- Red and purple sandstones (the Brownstones).
- Red and purple marls, with an occasional conglomeratic cornstone.

Messrs.
Strahan,
Tiddeman,
and
Wilkinson.

The last named are not often visible, and may be absent on Cefn-y-Bryn. The red sandstones, which are usually conspicuous, graduate up into the red conglomerate, but there is a fairly well-marked boundary between the red and white conglomerates. In one case noted by Mr. Tiddeman pebbles and fragments of hæmatite occur in the Old Red conglomerate.

The detection of Ludlow Beds in the Cefn-y-Bryn anticline has changed our views with respect to the development of the Old Red Sandstone. From a rough estimate the thickness of the latter formation in Cefn-y-Bryn can scarcely exceed 400 feet, though it amounts to 3,500 feet near Cardiff and to still more in the Brecknock outcrop. Moreover, in Rhossili Hill there are beds represented which are absent in Cefn-y-Bryn, and a greater thickness of the Brownstones and marls exposed, without reaching the base. The attenuation of the Old Red Sandstone in Cefn-y-Bryn takes place chiefly in the lowest subdivision, the marls with cornstones, which, indeed, are doubtfully represented by a few feet only; but the Brownstones also, though certainly present, are greatly diminished. The uppermost conglomeratic subdivisions, on the other hand, are well developed. It is clear therefore that the diminished thickness of the Old Red Sandstone is not due either to an overlap by the Carboniferous shales, or to an overlap of the Brownstones by the conglomerates, or apparently to an overlap of the marls by the Brownstones, but to attenuation in the two last-named. These facts suggest an unconformity between the red rocks and the Ludlow shales—a matter which will receive further investigation.

CARBONIFEROUS LIMESTONE.

North Crop.

Mr. Cantrill. In the North Crop Mr. Cantrill makes the following observations on the Carboniferous Limestone. It presents, in descending succession:—

Rottenstone Series.—Fine-grained, white and yellow sandstone with rotten chert-bands in the upper and rottenstones in the lower part.

Main Limestone 600 to 700 ft.	{	Dark limestones with black chert-nodules. Light-grey oolite about 50 feet thick; at its base about 15 feet of soft sandstone. Dark limestone and oolite. <i>Lithostrotion irregulare</i> at base.
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Lower Limestone Shales.—About 40 or 50 feet, but tending to thin westwards.

The Rottenstone Series has been exceptionally well exposed in the Bynea Brick Company's "plastic clay" level at Garnbiea. There the beds between the Millstone Grit and the top of the main limestone are about 60 feet thick. They consist of yellow sandy material in beds about six inches in thickness, some of which have the flinty and angular fracture, and occasionally the nodular form, of chert, while a very few contain a small core of

undecomposed chert. A band of black clay $1\frac{1}{2}$ feet thick, near Mr. Cantrill. the middle of the series, may be a decalcified limestone, and at the bottom there is a rottenstone, 12 feet thick, which, however, is too clayey for commercial purposes. The "plastic clay," for which the level is worked, appears to be an impalpably fine "silica-sand." It occurs in thin bands among the harder and coarser material.

Gower.

Notice has been previously made of some pitted and nodular Mr. Tiddeman. limestones, which had been observed by Mr. Tiddeman in the upper part of the Carboniferous Limestone at Newton Nottage and in Gower.* He now makes the further observation on these rocks that they are almost always associated with thin coaly beds containing carbonised vegetable matter, such bands having been noted by him at Newton Nottage, Oystermouth, Mumbles, Pwll-du Head, Oxwich Head, Bishopston, Ilston, Llethrid and Llanrhidian. From a smut-bed of this character at Oxwich Head he has obtained a number of small gasteropoda, which may prove to be new to Carboniferous rocks. The section is given by him as follows, in descending order:—

<i>Oxwich Point.</i>	ft.	in.
Dark crystalline encrinital limestone.		
Black compact limestone, seen to	20	0
Black calcareous mud with bryozoa		6
Crushed limestone with veins of calcite and <i>Productus</i> at top	2 ft. to	3 0
Brown or black muddy bed with gasteropoda and vegetable remains (? fucoids)	1 ft. to	3 0
Irregular limestone with <i>Lithostrotion</i> abundant, also <i>Zaphrentis</i> and <i>Euomphalus</i> , and occasionally <i>Stigmaria</i> ; base not seen.		

The nodular limestone series is quite 200 feet thick at Oxwich Head, and is exposed to a thickness of more than 200 feet at Llanrhidian. Mr. Tiddeman proposes to apply to it the name of Mumbles Head Beds.

With reference to the Rottenstone or Bishopston Beds,† Mr. Tiddeman writes that these strata, "as represented by the 'Black Lias' at Oystermouth and the decalcified limestone at Bishopston, have been traced over a wider area than was assigned to them by De la Beche. It is true that they are thickest at Bishopston, but we also find traces of them on the southern side of the peninsula. Thus the rottenstone occurs in pockets in the Mumbles Head Beds at Pwll-du Head, as well as overlying the same beds at Port Eynon at the old paint-mine and on the foreshore. At the paint-mine the *Spirifer* which abounds at Bishopston was found. Traces of the rottenstone have been detected on the northern margin of the Carboniferous Limestone at Ilston,

* *Summary of Progress* for 1900, p. 87.

† *Summary of Progress* for 1900, pp. 87, 88.

Mr.
Tiddeman.

Llethrid, near Cao Morgan, and Cil Ifor. At both the last-named localities *Wavellite* occurred, and they are probably the places hinted at by De la Beche where Logan found this mineral.*

MILLSTONE GRIT.

Gower.

The Rottenstone Beds are followed upwards by Millstone Grit, which consists chiefly of black shales, but at a distance from the limestone corresponding to a thickness of 100 to 300 feet, Mr. Tiddeman finds a fairly persistent bed of compact, almost cherty, sandstone, which breaks up into cubes or rhombs; this band is to be seen at intervals from Bishopston to Llanrhidian. A higher horizon of sandstone bedded with blue and black shale runs parallel with it from Pengwern Farm through the south end of Cillibion Plantation and by Parc-y-rhedyn, but not east from Bishopston. A third still higher sandstone runs through the north end of Cil Ifor Top, though not through the highest point of the hill. This rock has been quarried for building, and certain beds in it serve as freestones. The succession generally presents but little resemblance to that of the North Crop.

North Crop.

Mr.
Cantrill.

The main subdivisions of the Millstone Grit have been mapped by Mr. Cantrill through the area surveyed this year, but in a slightly modified form. The quartz-pebbles in the basement-grit become scarcer westwards and almost disappear near Careg Dwfán. At the same time bands of shale tend to come in near the base, and Mr. Cantrill thinks it possible that the radiolarian cherts† may be found in a black shale some 10 feet above the base of the grit.

Such a bed of shale has been exposed near the Garn-bica Level. It is 16 feet thick and contains lamellibranchs resembling *Posidonomya*, ostracoda, and plant remains; there occur also beds which look like rottenstones and decomposed chert, but between it and the Rottenstone Beds proper there are some few feet of quartz-grit. Similar shale-bands occur elsewhere, so that there would appear to be an alternating passage up from the Limestone into the Millstone Grit.

The middle or shaly subdivision of the Millstone Grit passes down into the underlying grits. The Farewell Rock or uppermost subdivision runs, as a thin band of olive-brown sandstone, south-westwards of Llandyfan and west of Llandybie.

COAL MEASURES.

The past year's work in the Coal Measures has lain in the North Crop between Glanamman and Llandybie, and in the South Crop between Swansea and Llanelly, including the north side of Gower.

**Mem. Geol. Survey*, vol. i., p. 134.

†Described in the *Summary of Progress* for 1900, pp. 88, 89.

North Crop.

In attempting to locate the base of the Coal Measures along the north side of the Amman Valley, between Glanamman and Ammanford, much difficulty has been encountered through the prevalence of Boulder Clay, the existence of obscure east and west rolls connected with the Tair Carn anticline, and the occurrence of several faults belonging to the N.N.W. system. Mr. Cantrill.

The lowest or Astell vein, which at Brynamman serves as a base to the Coal Measures, is represented possibly by a small vein which crops out at Bryn Pedol. Its outcrop probably passes through Cyngordy and Glyndreiniog to Tyllwyd, where it is thrown northwards by the Nant-main or Tyllwyd Fault—a large downthrow west. West of this fault, however, the base of the Coal Measures is conjectural; the lowest veins known being the group formerly worked at Tyllwyd and Brynllloi, which comprises probably the Little Brass, Middle and Lower Veins of Brynamman. Some little exploration has been made upon these, also a little south of Garenig Bridge, but west of the Cwm Garenig Fault their position is unknown; they are presumably thrown northwards and probably crop out under the Boulder Clay on the north side of the Amman. The parallel fault of Glyn Moch, which runs 500 yards farther west and is also a downthrow west, must throw them still farther north, for the Big and Brass Veins crop under the Boulder Clay between Ynys-y-fawnen and Aber-nant, where they were worked at the Llwyn yr haf Shaft and Drift. West of this point all workings between the Amman and the axial line of the Tair Carn anticline cease. Some veins which are probably low in the Coal Measures crop out and were formerly worked by openworks between Glynhir and Drefach; but their correlation remains doubtful. The same veins should rise again to the north near Llandyfan, but the ground is unproved as far west as the Dinas Fault, near Llandybic. Beyond the fault the lowest veins are known as the Piodau veins.

In the Amman Valley the various ironstones and coals—from the Big down to the Brynllloi—which were extensively worked at Glanamman are cut off by the Cwm Garenig Fault, and except at Llwyn yr haf are unknown between this fault and the Bettws Fault; the old cropworks at Pontamman and the veins at present worked in the Ammanford Colliery not having yet been satisfactorily correlated.

The Red Vein formerly worked at the old Cawdor Colliery in Cwm Garenig is there thrown down on the west by the Cwm Garenig Fault into the Amman Valley; and again further west by the Glyn Moch Fault. It was formerly worked at Glyn Moch Colliery, and the crop can be traced easily thence as far as the Bettws Fault. At the Red Vein workings of the Ammanford Colliery Co. a clod five feet thick comes in in the middle of the coal and persists westwards.

Several thin veins above the Red Vein have been worked along the crops on the high ground south of the Amman Valley.

Mr. Cantrill. One of these, known as the Butcher's Vein, has been traced from the Cwm Garenig Fault, past Waun-hir and the Butcher's Arms, into Cwm Cathan, where it is probably the Garn Swllt Vein. This may prove to be the representative of the Ynysarwed or No. 2 Rhondda Vein.

South Crop and Gower.

Mr. Strahan. Field work during 1901 was carried on by Mr. Strahan in the Coal Measures between Loughor and Llanelly and in the northern part of Gower. The inclination of the measures of the South Crop is always high, but in Gower, not far from the western end of the Coal basin, it approaches verticality, and is accompanied by a number of extremely sharp folds. The steepest dips and the folding occur along the outcrop of the lowest measures, which are almost wholly composed of shale; northwards the inclination steadily diminishes, and the massive sandstones which accompany the Dunvant Veins are not only free from folding but form a regular outcrop, interrupted only by the north and south faults. Still farther to the north, after passing a depression due to the outcrop of the Penlan Vein and some soft measures associated with it, we reach the dominant feature of the district, an almost continuous range of hills formed by the Pennant Series.

The Pennant Series, however, of this part of the coalfield differs from that of Monmouthshire in the fact that its upper part includes several valuable seams of coal and thick beds of shale. Thus the Hughes group of coals lies about 500 yards below the Four-Foot Vein, which we take as the top of the series, and crops out along a continuous strike-valley which runs from Swansea to near Penclawdd. Northwards this valley is dominated by a subordinate range of sandstone-hills, on which Wig-fawr and Allt-wen are situated, and this again is succeeded by a northward slope in which the Two-Foot, Three-Foot and Six-Foot Veins crop out, together with some subordinate sandstones. Finally at the edge of the low ground we reach the outcrop of the Four-Foot Vein and the top of those productive measures which we believe to correspond to the unproductive upper part of the Pennant of Monmouthshire.

Thus far the dip has been uniformly to the north, but at an always diminishing angle. The beds at length become horizontal under the alluvial flat north of Gowerton, and then gently rise to form a low anticline which runs through Mynydd Carn-goch, Loughor Upper Town, and south of Broadoak Colliery. The form of the ground, however, corresponds to the dip of the strata, so that the Four-Foot Vein keeps near the surface, without actually cropping out. This Broadoak anticline is followed northwards by a shallow syncline which runs north-westwards under Loughor Common, as proved in old workings in the Four-Foot Vein. The tract lying north of the syncline has not yet been proved. The measures strike due north and south for about two miles and include a group of three seams known as the Grovesend Veins besides one or more thin seams above.

There is much doubt whether the Grovesend Veins are Mr. Strahan. equivalent to the seams which crop out at Melin Llan* and Gelligynore, and, therefore, represent the Four-Feet Seam, or whether they lie above them. The Drift of the Mountain Colliery was commenced in the outcrop of one of the Grovesend Veins and then passed through an upthrow fault into the Four-Feet Vein, which was extensively worked and found to differ in section from any of the Grovesend group. This would seem to prove that the Grovesend group lies above the Four-Feet, but how far above is not known, the throw of the fault never having been proved. On the other hand the Grovesend Veins are said not to match any of the known seams which lie above the Four-Feet in the neighbourhood. A shaft in progress at Cefn-Arda has not thrown any light on the matter so far, for it was commenced a few yards below the Grovesend crop and has been sunk over 250 yards without proving any recognisable seam. If the Grovesend seams correspond to the Four-Feet Vein and Rider, the Five-Feet should have been found in this shaft at about 120 yards depth, and the Six-Feet at about 250 yards depth. Yet if they lie above the Four-Feet, they can hardly be so high above it as the Cefn-Arda shaft seems to indicate, for it would imply that the fault traversed at the Great Mountain Colliery had a throw of not less than 200 yards, in which case it should be traceable both to the north and south of the doubtful region.

Two seams occur above the Four-Feet near Loughor, namely the Loughor Little Vein, 41 yards above it, and the Penyscallen 20½ yards above the Little Vein; a third which is not known to exist near Loughor has been worked to the west of the Loughor Vein under the name of the Gelli Vein; this lies 188 yards above the Four-Feet, and, therefore, corresponds in position to the Drews Vein of Llansamlet and the Bryncoch Vein of the Neath trough. This is the highest vein known in the South Wales Coalfield; it occupies an area of less than a square mile in extent on the east or downthrow side of the Bryn-serfyll Fault.

The sequence of the veins in the Llanelly district corresponds well with that of the Swansea district, but the names are different. A correct correlation is important in estimating the number of seams, if any, that are likely to exist in the Llanelly district beyond those which have been already proved. The accompanying table gives the correlation and the synonyms so far down in the series as the surveying of the district has proceeded. It should be especially noted that the Four-Feet Vein of Swansea becomes the Big Vein of Box and St. David's Collieries, and that the Four-Feet Vein of those Collieries is the Five-Feet Vein of Swansea.

* *Summary of Progress* for 1900, p. 99.

Comparative Table of the Seams above the Hughes Vein between Llanelly and Neath.

(Distances between seams are given in yards.)

Llanelly District.			Loughor.	Swansea District.	Neath District.	
Old Castle Colliery.	St. David's Colliery.	Cae Colliery.				
Rosy Vein 18	Gelli Vein 119½	Clement's Vein 39 Glyngwernen, or Box Big Vein 83 Box Five Feet Vein	Penyscallen Vein 20½	Drew's Vein 135 to 180	Bryn Coch Vein 152	
Fiery Vein 36	Coal, 1 ft. 10 in. 11½		Loughor Little Vein 41			
Golden Vein	Coal, 1 ft. 3 in. 56		Broad oak Vein 96	Four Feet Vein 118	Wernfraith Vein 105 to 110	
Bushy Vein 34	Four Feet Vein 98½		Five Feet Vein	Five Feet Vein	Greenway or Court Herbert Vein 115 to 130	
				76 to 87 Jenkin or Morris Vein 44 to 54	Tir Edmond Vein 25	
	Rosy Vein 64½	Rosy Vein 69½		Six Feet Vein 12 to 20	Graigola Vein about 25	
	Fiery Vein 24	Fiery Vein 44		Three Feet Vein	Upper Maesmelyn Vein 53	
		Golden Vein		38 to 49 Two Feet Vein	Lower Maesmelyn Vein	

Returning to the seams in and below the Pennant Series we find that the Hughes Vein has been extensively worked from Swansea to the shores of the Loughor Estuary, though the other veins which belong to the Hughes Group have been touched here and there only. The mass of Pennant rock, which lies below the Hughes Group, contains the Cuckoo Vein, which has been proved near Cockett, but seems to be of secondary importance. At the base of this rock the Penlan Vein has been worked at intervals from near Dunvant to Penclawdd. Eastwards it runs near Hendre-foilan, but is then lost to view under the great mass of gravel of Sketty and Swansea; there is reason to believe, however, that it corresponds with the Dyvatty Vein,* and is therefore, the nearest equivalent we can find to the Rhondda No. 2 Seam.

The Penlan Vein forms the highest of what are known as the Dunvant Veins. Of these the most persistent are, in descending order, the Penclawdd Big Vein (the most important), the Glamant and the Gleilyd, while a fifth, known as the Rock Vein, exists westward only of Dunvant. The Dunvant group is associated with massive sandstones, the Penclawdd Vein especially having so strong a rock above and below that it crops out along the top of a strike-hill and not along the bottom of a strike-valley as was the case with the Hughes and others. These massive sandstones no doubt correspond to the Llynfi rock,† which is associated further east with the Tormynydd Vein.

The Dunvant Veins crop out close to the station of that name and run thence to the sea near Penclawdd, their position being marked by numerous old, as well as recent, crop-workings. Their position under the gravel of Sketty and Swansea has never been ascertained, nor indeed in any part of Swansea Bay except in the shore of Baglan Bay.

From the Dunvant rocks downwards the Coal Measures consist chiefly of shale—a fact which has contributed to the plication, and which renders the unravelling of the structure extremely difficult. One well-marked group of seams traverses the whole peninsula from Clyne to Glan-Morlais; it includes the following seams in descending order:—The Frog Lane, the Big or Six-Foot, the Yankee, the Four-Foot and the Three-Foot, the thickness of measures between the Frog Lane and Three-Foot Veins amounting to 119 yards. The coals of the Glan-Morlais group are highly bituminous, and are now worked at and east of Glan-Morlais. In Clyne Wood where they were worked a few years ago they are said to have been too soft to be of much value.

The sharp folding which has been alluded to as occurring in the lower measures affects the Glan-Morlais group. Though the outcrops are regular from Glan-Morlais for about a mile, they become untraceable near Pen-llwyn-Robert, and the reason is apparent in the workings of the Morlais Vale Colliery, where the veins have been thrown into a series of steep east and west folds. Similar folding is seen between Killay and Mumbles Road Stations.

* *Summary of Progress for 1900*, pp. 93, 94.

† *Summary of Progress for 1900*, p. 94.

Mr. Strahan. Some distance below the Glan-Morlais group we come to the Farm Vein which has been worked north and north-west of Wern-ffrwd, and is said to be 3 feet 6 inches thick; and the Lynch Rider and Lynch Vein, which is said to be 2 feet 6 inches thick. These were worked a few years ago at Wern-ffrwd, and westward from that place the outcrops are marked by continuous old workings for about a mile, the dip being always high and sometimes reaching verticality. These veins are not continuously traceable across the peninsula, for the strata are intensely squeezed and the outcrops have not the regularity which characterise those of the Pennant Measures. In some places, as happens with the Farm and Lynch Veins near Rallt, two outcrops approach so closely that it is evident that many strata have been squeezed out. Compensation is found close by where the outcrops diverge to more than their normal distance, the extra intervening space in such a case being filled up by plications.

The Lynch Vein is the lowest known seam in Gower. It is succeeded downwards by thick shales with an occasional bed of sandstone, but it is not till we have travelled 500 yards south from the Lynch Vein that we see any noteworthy outcrops of the harder rock. These form a long strike ridge on which Llan-Elen stands, and run along the northern margin of Clyne Common to near Clyne Castle. They have shared, however, in the plication, and both in Clyne Park and along the valley north of it they have been doubled up into a series of sharp synclines and anticlines, a fact which combined with the scarcity of sections makes it impossible to trace their outcrop across the peninsula with precision. These sandstones we take as the top of the Millstone Grit, but it should be understood that the separation of the Coal Measures from the Millstone Grit is purely arbitrary. It is founded neither on palæontological evidence nor on any marked lithological distinction, but is adopted to bring the sequence in Gower into accordance with the sequence elsewhere. That the grits of the Millstone Grit are represented by the shales in Gower is certain; but by how much of them is doubtful. The Llan-Elen sandstones form a convenient horizon for mapping purposes, and not improbably represent the Farewell Rock of other regions.

The coals of the region described above are all bituminous, though the measures, from the Penlan Vein downwards, correspond to the measures of the North Crop, in which all the seams are anthracitic.

A number of normal north and south faults cut across the east and west folds of Gower. They can rarely be traced far, though locally their throw may be large. The Dunvant Fault, for example, though large at Dunvant, is non-existent at Bishwell, though it may turn westwards and join the Alltwen Fault. Several faults have been proved in the Penclawdd Vein near Killan-fawr, the largest being a downthrow west of 99 yards. These faults break through the crop of the Hughes Vein also, and one of them has been proved in the Four-Feet, but it is questionable

whether they can be identified near Loughor. In that neighbourhood three faults are known to exist; one was crossed in the Mountain Colliery referred to above; a second was proved in the Pengrys Pit, and is estimated to be a downthrow west, of 120 yards, from a consideration of the difference of level of the Four-Foot Vein at Broad Oak and Loughor Upper Town; the third is a downthrow east, reputed to amount to 200 yards, which has been touched under the estuary of the Loughor above Loughor Bridge. This is approximately in line with a fault which cuts all the outcrops from the Hughes to the Gleilyd near Berth Llwyd in Gower, but which is a downthrow west. Of others mention may be made of a fault of 120 yards downthrow west, which has been traced from the Penlan Vein at Trinity Church in Penclawdd to the Big Vein near Glan-Morlais Station. In the Llanelly District the principal north and south faults are the Bryn-Serfyll and the Box Bar Fault, both large downthrows to the east. Mr. Strahan.

TRIAS.

The occurrence of Triassic outliers in Gower has long been anticipated,* but not proved until the past year. The anticipation was founded on the existence of a high level plane apparently of marine denudation, sufficiently obvious to the eye when on a level with it, but especially significant when it is realised that it is composed of highly inclined strata of widely different hardness. Many of the veins, moreover, in the limestone had served as conduits for a red stain, while some contained hæmatite, strong evidence of the former existence of Trias not far overhead. Two occurrences of Trias may now be recorded. At Port Eynon an excavation from which shale was raised for the manufacture of paint has disclosed the edge of a massive Triassic conglomerate, which is described by Mr. Wilkinson as follows:—"The conglomerate rests upon almost vertical black shales belonging to the Bishopston Series and lower part of the Millstone Grit. The matrix is pinkish, and in places of a soft clayey nature; the boulders, which are large and abundant, have been derived chiefly from the Carboniferous Limestone, but include many of black and grey chert, derived no doubt from the shales above the limestone."

The other locality referred to lies some distance farther west. The Trias occurs in a swallow-hole or chasm in the limestone, due to collapse along a line of fault. The rock is a deep-red sandy marl, variegated with spots and streaks of green. In it are imbedded masses of limestone and calespar fallen from the walls of the chasm, which obviously was open and undergoing enlargement in Triassic times. A somewhat similar case was recorded in the *Summary of Progress* for 1898, p. 134.

RAISED BEACH.

The sequence of deposits associated with the Raised Beach of Gower was described in the *Summary of Progress* for 1899, pp. 154, 155. During the past year the same sequence has been

* See Tawney, *Proc. Bristol Nat. Soc.*, Ser. 2, vol. i, p. 165.

Mr. Strahan. observed by Mr. Wilkinson on the north coast between Burry Holms and Hills Tor and on the south side of the Worms Head. Here the beach is little below the 50 feet contour, but between Tears Point and Mewslade Bay it is not more than 15 or 20 feet above sea-level, while from Overton Mere to Oxwich Point it lies just above high-water mark.

GLACIAL.

In an examination of the Glacial phenomena of South Wales, the fact that the Brecknock Beacons formed an ice-parting claimed early attention. Though boulders derived from them are distributed freely over parts of Monmouthshire and Glamorganshire, no rocks from farther north found their way across them. Later on a similar observation was made with respect to the Pennant escarpment which culminates in Carn Mosyn at a height of nearly 2,000 feet. From this also boulders were carried in abundance southwards, though none succeeded in crossing it from the north. The escarpment, together with others, therefore played the part of a subsidiary ice-parting, for it by no means formed the northern limit of glacial action, but merely acted as a local obstacle to the southward movement of the Brecknock ice, at the same time that it gave birth to a small flow of its own. Recent work tends to show that the Brecknock Beacons themselves played a similar part with reference to the glacial system of Wales, though on a larger scale.

The range formed by the Brecknock Beacons, the Carmarthen Fans, and the Black Mountains, diminishes in height westwards, until in the region now under examination the escarpments of Lower Carboniferous Rocks and Old Red Sandstone rarely exceed 600 feet in height, while they are traversed by valleys or cols descending to 400 or 500 feet above the sea, and one valley, followed by the railway, descending to 200 feet. In the same region the valley of the Carmarthen Towy takes its course along the northern side of the range, and at no great distance from it, the bottom of the valley being about 60 or 70 feet above the sea. Notwithstanding this difference in level, Mr. Cantrill has found repeated proof both in the direction of the striæ and in the dispersal of boulders, that the ice mounted the escarpment and passed over it southwards.

The ice which occupied the Towy Valley travelled down that valley westwards as a whole, and the fact that a part was driven across the escarpment southwards can be explained only on the supposition that the valley was filled to overflowing, and that a region in Central Wales, of which the glacial phenomena are as yet unknown, was buried under ice of great thickness.

Mr. Cantrill. The observations upon which these conclusions are founded have been made chiefly by Mr. Cantrill. He reports as follows:—The ice-movement was parallel to the main features with a tendency to swing southwards when approaching a gap in the Tilestone ridge; thus the striæ near Cilmaenllwyd point S. 52° W., but nearer to the gap of the Cennen Valley they change gradually to

S. 20° W.. Moreover much Silurian detritus occurs in the Mr. Cantrill. Boulder Clay which overspreads the outcrop of the Old Red Sandstone in the Cennen Valley, though very few boulders of the Old Red Sandstone can be found on the Silurian outcrop. Lastly, a limestone quarry half-a-mile south of Ffairfach shows the edges of the beds turned towards the south, as though by the passage of ice up the valley. It is clear, therefore, that the main movement was from the north-east, and was due to a great accumulation of ice in Central Wales.

Evidence of similar movement has been obtained by Mr. Cantrill on the Millstone Grit scarp between the Cennen and Loughor Valley, near Llandybie. Careg-Dwfan, 926 feet in height, has been striated by ice, which crossed it from the north-east, on its way to the Loughor Valley. A flow passed also through the Millstone Grit gap at Llandybie, but was deflected by the local configuration to a direction S. 15° E. The high Pennant scarp, south of the Amman Valley, was over-ridden by ice forced southwards, a fact which explains the occurrence of many Old Red Sandstone and limestone boulders in Cwm Cathan, and of an abundance of fragments of Silurian mudstones in Nant Ffin, at a distance of six or seven miles from the nearest Silurian outcrop.

Mr. Cantrill notes also the occurrence of conspicuous masses of gravels of late glacial age, where the Cennen leaves the strike-valley west of Trapp, and debouches upon the broad north and south valley followed by the railway. These gravels have been derived from the Cennen Valley, but take a moundy form which is not observable in river-terraces formed under existing conditions. They were probably the work of effluents from the ice-sheet, during a late period in its existence. From the fact that they extend southwards, it seems probable that the effluents took that direction, and not the northward course now followed by the Cennen.

To the west of Swansea there is a great development of Mr. Strahan. mounds and ridges of gravel. The deposit covers the whole of the slopes extending from the shore to the foot of the Pennant scarp, nor has its base ever been reached, either in the lower part of Swansea or near Sketty. Clyne river has cut through it to the Coal Measures, and the rock crops out in the fore-shore at Liliput, in both cases near the western limit of the gravel tract. Part of the deposit is a tumultuous assemblage of well-rounded boulders up to 6 or 8 inches in length, imbedded in a gravelly matrix, but the deeper sections usually reveal roughly stratified sand and gravel; in an old brick-pit near Clyne Colliery the gravel is associated with a deposit consisting of alternations of fine sand and laminated loam, such a sediment as would be formed in tranquil water into which sediment was being poured rather copiously. The gravels have been thrown down everywhere in hummocks and ridges, enclosing hollows, and the character of the laminated deposit suggests that it was laid down in one of these hollows; glacial conditions still prevailed, however, for the loam was subsequently buried under a few feet of Boulder Clay.

Mr. Strahan. The boulders of the Swansea and Sketty gravels include, in order of abundance, Coal Measure grits, white pebbly grits, and Old Red Sandstone. That the material was derived from the North Crop, by way of the Swansea Valley, seems certain, but the source of the pebbly grits is open to doubt. Some much resemble the pebbly Silurian passage-beds, but they have yielded no fossils.

The gravel-ridges generally run parallel to the Pennant escarpment, but a few large hummocks jut out from the hillside in a southerly direction, as, for example, on either side of the valley running down from Cockett to Sketty. Both at Swansea and Llanelly the direction of transport seems to have had a strong westward trend, wherever the local configuration of the ground permitted. The spit of land which projects into the estuary south of Llanelly owes its existence principally to a mound of glacial gravel, and to a shingle-ridge derived from it. A cliff, about 60 feet high, shows a very coarse, roughly stratified gravel with beds of sand, contorted in places. The boulders range up to 2 feet in length and the assemblage resembles that of the Swansea gravel. A bore-hole put down on the eastern slope of the mound is said to have passed through 120 yards of loose material before reaching solid rock. Several other gravel-mounds project through the alluvium between Llanelly and Loughor Bridge, in a tract on which the mining information has not yet been collected.

Striations on rock-in-place are scarce everywhere near the southern margin of glaciation. The southernmost striae observed during the past year occur in a quarry at Allt, near Llangennech (Sheet 230). They range W. 35° S., and point clearly to the ice having had a more westerly trend than has the Loughor River. None have been found in any part of Gower, though striated boulders are common.

Mr. Tiddeman. A long crescentic ridge, on the top of an east and west hill on Welsh Moor, is described by Mr. Tiddeman as looking like the terminal mark of a glacier or ice-sheet, momentarily advancing during its retreat northwards. The east and west arrangement of mounds of gravel and Boulder Clay, between Killay and Fairwood suggest the same kind of action. But, on the other hand, he considers the gravel-mounds at the confluence of several streams above Bishopston to have more probably been due to the action of glacial streams on the material brought by the ice-sheet. As throwing light on the direction of transport Mr. Wilkinson notes that boulders of Old Red Sandstone are far more numerous on the south than on the north sides of the hills formed by that rock. To this may be added the fact that Coal Measure detritus abounds in the Drift far to the south of the base of that formation.

Mr. Strahan and Mr. Wilkinson. Some of the Drift, and especially the lowest part of it, is of strictly local origin. Thus in the fine section of Rhossili Bay there rests immediately upon the limestone an accumulation composed almost wholly of limestone-fragments, while above this again, with a fairly definite base, comes a mass of gravel in

which well-rounded far-travelled boulders of Coal Measures, Old Red Sandstone, &c., predominate. Again, in the centre of the bay the cliff is composed of boulders derived from the hill-slope above, but close by, to the north and south, the Drift of more distant origin comes in on top of the purely local material. It is worthy of note that this mass of local Drift lies just opposite a hollow in the hillside.

Mr. Strahan
and Mr.
Wilkinson.

Several large domes of stratified sand and gravel have been noted by Mr. Wilkinson. From the general gravelly character of the Boulder Clay, especially near the surface, there is always much difficulty in separating it from the sand and gravel.

ECONOMICS.

The ground surveyed during the past year is almost wholly pasture, but little more land on each farm being kept under the plough than is necessary for the wants of the farmer. The soil yielded by the Glacial Drift, whether of the type distinguished as "Boulder Clay," or that as "Sand and Gravel," may all be classed as gravelly. There is a considerable area of salt marsh in the estuary of the Loughor which is valuable as pasture, and the gathering of cockles in the tidal sands beyond constitutes an important industry. Parts of the Millstone Grit and Pennant Grit outcrops consist of mountain land, but such tracts are far less extensive than in the central parts of the coalfield. The steeper slopes of the hills are utilised for the growth of pit timber.

Mr. Strahan.

Among economic products apart from coal may be mentioned the Carboniferous Limestone burnt at Llandybie and Oystermouth (both white and so called "Black Lias" limestone), and the Llandilo Limestone at Llandilo. Building-stone is obtained chiefly from the Pennant Grit, at Pen-y-Fan, Duvant, and Cockett; and paving-stone from a quarry between Llanelly and Felin Foel. The Tilestones were formerly quarried for roofing. Clay for puddling is dug on the foreshore at Swansea, and rotten-stone is worked to a small extent in the Upper Limestone Shales of the North Crop, but a more important industry consists in the quarrying of the more purely siliceous bands in the Millstone Grit at Carn Bica for the manufacture of fire-bricks at the Bynae Brick Works near Llanelly. "Plastic clay," an impalpably fine siliceous sand, is worked by level near the same place. Millstone Grit shale, stained purple or red by infiltration from Trias, used to be ground up and made into paint near Port Eynon.

4. EXAMINATION OF NEW RAILWAY AND OTHER SECTIONS.

NOTES ON A NEW RAILWAY IN COURSE OF CONSTRUCTION BETWEEN AXMINSTER AND LYME REGIS.

BY H. B. WOODWARD.

The railway, which is a "light" one, starts from the main line of the London and South-Western Railway a little south-west of Axminster station, and at an elevation of about ninety feet.

Mr. Woodward.

It follows a serpentine course to Combe Pyne Hill, attaining an elevation of about 415 feet, and after passing through Uplyme, terminates to the north-west of Lyme Regis at an elevation of about 240 feet.

In a shallow cutting by the main line, valley gravel was seen to rest irregularly on the Keuper Marl. The gravel consists for the most part of rough flint and chert stones, with pebbles of quartz and dark grit. Stones occur some way down in the Keuper Marl, having probably descended through cracks formed in dry weather; but here and farther on there are evidences of considerable soil movements and small landslips which have led to the incorporation of gravel with red marl.

Thus by the orchard south-west of Shools Farm there was an interesting section of the valley drift, a good deal disturbed, and showing gravel with patches and bands of red Keuper Marl, which in the re-arranged condition showed little or no variegation. (Fig. 1.)

Below the railway by Abbey Gate Bridge the road-cutting showed pockets of gravel in the red and variegated Keuper Marl,

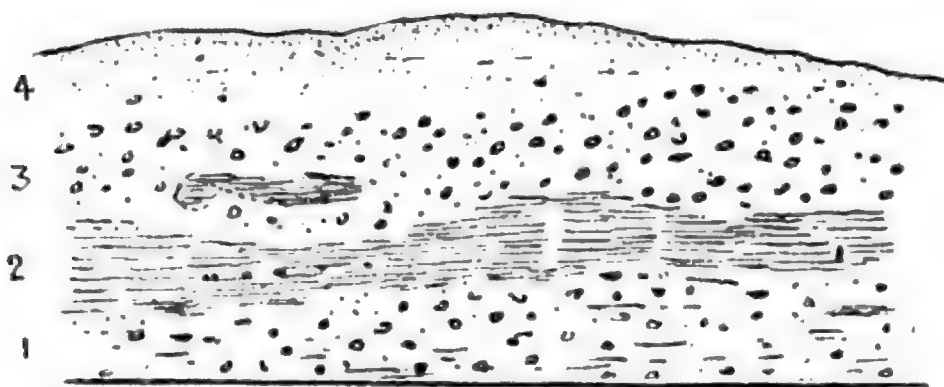


Fig. 1. Section south-west of Shools Farm near Axminster.

- | | | |
|-----------------------------------|--------------------------|-------------------|
| 4. Soil and sandy loam. | 2. Red marl with stones. | } 8 to
9 feet. |
| 3. Gravel with patch of red marl. | 1. Clayey gravel. | |

a feature perhaps due to the effects of subterranean stream erosion.

Southwards a broad patch of gravel extends to near Bean Close Coppice, where grey and greenish marls appear above the red and variegated Keuper Marls, forming the passage-beds into the Rhaetic formation.

By the bend of the railway, north-east of Great Trill, a striking section was displayed of inclined and banded red and variegated Keuper Marls with overlying and partially interbedded gravel—an arrangement evidently due to the slipping of a mass of ground, and during the process some slight faults were produced in the Keuper Marls, which have a north-westerly dip. The features occur on the spur of a hill. (Figs. 2 and 3.)

Further south, near South Ground Linhay, there is a cutting in the Keuper Marls, comprising red and variegated marls and a conspicuous band of hard pale marl, overlain by grey, green, and red marls, and higher up by grey marls.

These strata were hollowed out on the eastern bank of the Mr. Woodward cutting to a depth of 20 to 25 feet, nearly to the level of the railway, the cutting being about 30 feet deep, and in the hollow was a mass of sand and chert detritus derived from the Upper Greensand. On the western bank, towards the valley, where the cutting is lower (18 to 20 feet deep) there was a wider spread of Greensand *débris*, and the Keuper Marls showed evidence of slight anticlinal disturbance, which may have been due to the breaking away of a mass of Greensand from the uplands of Trinity Hill on the east. (Figs. 4 and 5.)

North side.



South side.



Figs. 2 and 3. Railway-cutting north-east of Great Trill near Axminster.

2. Gravel.

1. Keuper. Red marl with bands of green marl. } Up to 12 feet.

In following the railway towards Newlands Coppice the cutting (in course of construction) showed pale and dark grey marls, with irregular patches of chert detritus. By the Coppice there was a trace of black clay, evidently a portion of the Rhaetic (*Avicula-contorta*) Shales, as the soil above contained fragments of White Lias.

To the south-east of Newlands Farm there is a long cutting from 10 to 25 feet deep in red, brown, grey, and greenish sands of the Upper Greensand, capped most irregularly by chert detritus. Irregular broken bands of chert, moreover, appeared at various levels. Here unquestionably the Upper Greensand, which comprises sands with bands of chert of varying thickness, had been disintegrated by the action of the weather, and the mass had been affected by a certain amount of land-slipping. Further on by Hartgrove Farm there was much rough chert detritus resting on the Greensand.

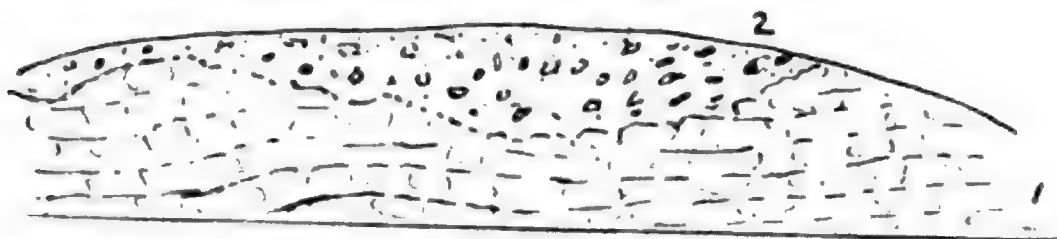
A different deposit was exposed to the south of Hartgrove Farm, being reddish brown loamy clay with angular and unworn flints, 10 or 12 feet thick. This may belong to the beds noted further on by Combe Pyne station. In the intermediate ground, comprising moorland and plantations, the Upper Greensand was exposed in places, but the land was for the most part covered with angular chert detritus, or "run of the hill" from the high ground of Shapwick Hill on the east.

Mr Woodward.

East side.



West side.



Figs. 4 and 5. Sections near South Ground Linhay, south of Axminster.

2. *Débris* of Upper Greensand - sand and chert.

1. Red and variegated Keuper Marl with band of hard pale marl.

Where the railway cuts the northern part of Combe Pyne Hill, a cutting (not completed) showed 3 or 4 feet of loamy flint drift resting on 5 or 6 feet of irregular and disturbed pipe-clay, whitish and pinkish in colour, and with black coatings on the joints, in irregular pockets, and on imbedded stones of flint and quartz. The black coating was determined by Dr. Pollard to be manganese-ore. The stones occurred in a band, the quartz pebbles varying in size from that of a pea to $\frac{3}{4}$ inch in diameter.

The appearance of these deposits suggested a possible trace of Bagshot Beds. Quartz pebbles had not been noticed in the plateau-deposits previously met with along the railway.

The suggested age of the beds was confirmed in cuttings further south, where unctuous white clay and white sand with flints were exposed. The beds evidently formed part of the series seen on the northern part of Combe Pyne Hill, but they were much concealed beneath a downwash of angular flint and chert detritus.

The clean white sand had every appearance of Bagshot sand, and on submitting a sample to my colleague, Mr. H. H. Thomas, he determined the ingredients as noted in the accompanying statement. The minerals are suggestive of derivation from a granitic area.

NOTES ON THE BAGSHOT SAND, FROM COMBE PYNE, IN DEVONSHIRE.

BY H. H. THOMAS.

This sand, which is very fine, is of a dirty white to a pale yellow colour, and is gritty between the fingers.

Large grains are rare, and there is a complete absence of calcareous matter in the form of carbonates

The following are the chief minerals which constitute the heavy Mr. Thomas. residue—that part of the sand with a specific gravity greater than 2.9:—

Rutile. This mineral, which is perhaps the most prevalent of those in the heavy residue, occurs for the most part in rounded prisms of an amber colour. Polysynthetic twinning is common, the striae making about 25° with the long axis. Geniculate twins also occur, following the same law of twinning as the above; the axes of the individuals being inclined to one another at near 65°.

Zircon. In rounded prisms and grains with fresh fracture, containing many colourless inclusions arranged parallel to the prism faces and to the pyramid (111).

Tourmaline. This mineral occurs in dark brown pleochroic prisms, which in some cases show the outlines of the simple rhombohedra. The grains have not been rounded to any great extent.

Leucoxene. In yellow, green, and white, almost opaque grains, all more or less rounded; in some cases there is evidence of an unaltered dark core, probably *Ilmenite*.

Micas. A white mica occurs in minute flakes.

Of the lighter residue, Quartz and Felspar are the main constituents:—

Quartz. In small angular grains, full of minute inclusions. Very few grains are rounded, and there is no evidence of secondary growth. As might be expected, this mineral forms the main bulk of the sand.

Felspar. The only felspar noticed was orthoclase; it exists in rectangular cleavage fragments, all more or less decomposed, in some cases so much so as to render them almost opaque.

This mineral, although not so plentiful as the quartz, occurs in fair quantity.

Round dark grains were found to consist of an earthy material, giving the reactions of manganese.

These grains probably consist of carbonaceous matter (? wood), associated with an earthy oxide of manganese.

Additional evidence in support of the Bagshot age of the beds was obtained in the long cutting east of Combe Pyne Station. This cutting is 35 feet deep in places, and although unfinished it showed a series of white, red and mottled stony clays and grey loam overlaid by rough flint and chert gravel. The clays had a marked inclination towards the east, but the dip was obscured in the upper part of the section, probably owing to the fact that the beds have suffered from prolonged sub-aërial action. The character of the deposits, and the remarkable inclination of the layers reminded me at once of the white and coloured clays and sands and coarse gravels which border the Bovey Basin at Wolborough and other places near Newton Abbot—beds which I had many years ago regarded as equivalent to the plateau drifts of Haldon,* and which have recently been shown by Mr. Reid to be for the most part of Bagshot age.† (Fig. 6.)

Mr. Woodward.

* *Quart. Journ. Geol. Soc.*, vol. xxxii., p. 234.

† *Ann. Rep. Geol. Survey for 1895*; and *Quart. Journ. Geol. Soc.*, vol. liv., p. 234.

Mr. Wood-
ward.

It is noteworthy that in the last *Summary of Progress* (for 1900, p. 122) Mr. Reid remarked that "Though the mapping of the Hampshire Basin has now been completed, it is probable that a chain of outliers of the Bagshot river-gravels will connect the Eocene of Dorset with that of Bovey Tracey in Devon—indeed, several outliers of this gravel have already been mapped."

Thus outliers have been traced as far west as the neighbourhood of Maiden Newton, in Dorsetshire, by Mr. L. W. Hinxman and Mr. E. E. L. Dixon.*

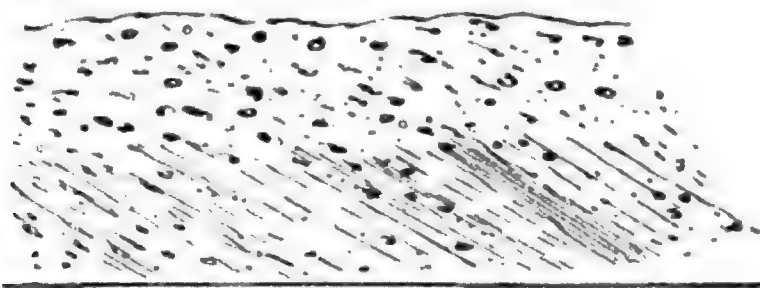


Fig. 6. Section east of Combe Pyne Station.
Bagshot Beds. White and red stony clays and gravels.

The foregoing remarks by Mr. Reid were not present in my mind while examining the cutting at Combe Pyne; it was therefore an additional satisfaction to read them afterwards. During the years 1873 and 1874, Mr. Ussher and myself, and in 1874 Mr. Reid also, were engaged in re-surveying the country round Honiton, Axminster, and Lyme Regis, and we were then perplexed to account for the plateau deposits. Some were evidently local, but in other tracts there were foreign materials, large pebbles of quartz, and quartzite, for which it was difficult to account. I was led to treat as probably Boulder Clay, a mixed deposit found at Yarcombe, between Honiton and Chard.† It seems quite likely now that this deposit, which comprised greenish-yellow clay, reddish-brown and pale-coloured sand, and gravel with quartz and quartzite, as well as flint and chert, may belong to the Bagshot series.

Leaving Combe Pyne Hill, the new railway extends eastwards towards Uplyme, along a scarp of Upper Greensand just below the Chalk. The chert beds of the Greensand here, as elsewhere, were of somewhat irregular occurrence in the sands, and where shattered by frost, they have formed a kind of angular drift on the slopes.

Beyond the viaduct which crosses the deep valley south of Cannington Farm, the Greensand was well exposed with little detritus on top, but further on below the steep scarp of Horseman's Hill, which is formed by the chert beds, the ground was covered with cherty *débris*.

West of the Uplyme road the chert and flint detritus was seen to rest most irregularly on grey and greenish sand of the Upper Greensand, owing chiefly to slips. Here the gravel contained a good deal of very red clay, with irregular brown and blackish

* *Summary of Progress* for 1898, p. 145; for 1900, p. 122.

† *Geol. Mag.*, 1874, p. 335.

layers, but it was less distinctly stratified than that in the lower part of the Combe Pyne cutting. Mr. Woodward.

Towards Lyme Regis station a somewhat similar section of 9 or 10 feet of gravel was seen above dark green sand belonging to the Upper Greensand.

FURTHER NOTES ON THE CUTTINGS ALONG THE SOUTH WALES DIRECT RAILWAY.

BY H. B. WOODWARD.

Particulars of the strata exposed along the cuttings of this railway were given in the *Summary of Progress* for 1898, pp. 188-192, from notes furnished by Mr. A. Strahan and myself. During the autumn I re-examined the cuttings from Wootton Bassett to Alderton. In the upper part of the cutting west of Hunt Mill Lane, Wootton Bassett, a band of coarse oolite belonging to the Corallian was exposed below the rubbly coral limestones and clays which form the upper part of that formation. No evidence of Lower Calcareous Grit was discernible, and it is possible that the beds are faulted against the Oxford Clay, but as the cutting had been sloped, precise evidence was not obtained. Onwards to near Hullavington the line has been nearly completed and all the cuttings have been sloped. Scattered flints (some of Eolithic type) are to be found above the Oxford Clay west of Brinkworth, and they are strewn over the ground to the north on Ramps Hill and beyond. These flints are gathered from the fields for road-mending, and they sometimes occur in sufficient mass for the opening of a shallow gravel-pit.

The cutting west of Bradfield Farm, Hullavington, had been considerably deepened since my former visit, and it exhibited an interesting section of Cornbrash resting on inclined layers of Forest Marble as shown in the accompanying diagram. (Fig. 7).

While the Cornbrash oversteps the inclined layers of Forest Marble clay and shale, these beds of Forest Marble themselves rest irregularly on a lower portion of the formation, a sandy division: so that there is evidence of a double (minor) unconformity—due partly to current-bedding and local erosion. At the top of the Forest Marble clay there is a thin oyster-bed made up of variable forms of *Ostrea Sowerbyi*. This is a feature of some interest. Oyster-beds occur here and there throughout the Jurassic system, but this is the most prominent bed that has been noticed in the Forest Marble of the west of England.

During an excursion made in May 1901 by the Geologists' Association,* the cutting was examined, and attention was then drawn by Mr. W. Whitaker to the fact that Cornbrash here lies on different divisions of the Forest Marble.

Sections of equally noteworthy character were observed by myself in cuttings along the Midland and South-western Junction Railway near Cirencester.†

* *Proc. Geol. Assoc.*, vol. xvii., p. 144.

† *Jurassic Rocks of Britain*, vol. iv., p. 366.

Mr. Woodward.

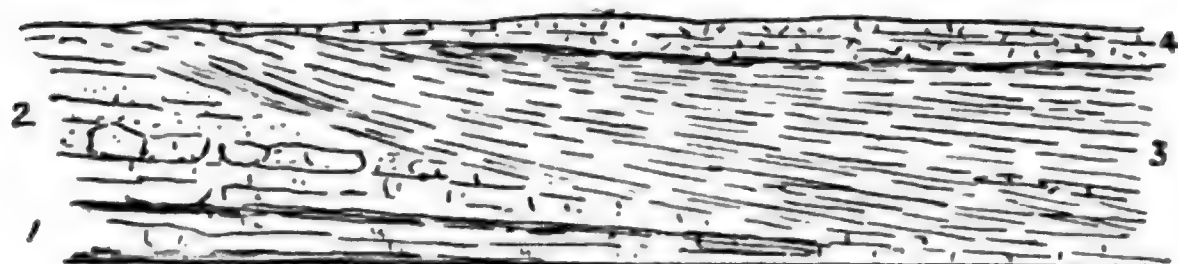


Fig. 7. Cutting west of Bradfield Farm, Hullavington.

4. Cornbrash. 2. Sands, sandstone and shaly beds.
3. Shales with thin calcareous grit. 1. Limestones, shales and clays.

It is not easy to build up the sequence of Forest Marble, and here and there small faults affect the strata and their amount and throw cannot always be definitely ascertained.

The following appears to be the succession between Hullavington and Alderton:—

Cornbrash.

Forest Marble.	Oyster Bed with <i>Ostrea Sowerbyi</i> : - - -	8 in. to 10 in.
	Clays with thin layers of calcareous grit with track-markings - - -	20 ft.
	Shales and limestones - - -	5 "
	Sands and hard calcareous sandstones -	20 "
	Oolitic and shelly and gritty limestones, with lignite and shales—false-bedded—and to some extent replacing one another -	35 to 50 "
	Blue clay with occasional bands of limestone	25 "

Great Oolite. Pale oolite. Seen to depth of 18 feet at Alderton.

The sands and sandstones are approximately equivalent to the Hinton Sand and Sandstone of William Smith. They exhibit large doggers with the well-known pot-lid structure. The limestones are manifestly impersistent.

REPORT ON THE EXAMINATION OF THE SECTIONS AT THE RESERVOIRS AND ALONG THE COURSE OF THE AQUEDUCT OF THE BIRMINGHAM CORPORATION WATERWORKS, RHAYADER TO FRANKLEY, 1901.

BY T. C. CANTRILL.

During the month of August about a fortnight was devoted to examining the sections at the reservoirs west of Rhayader and along the course of the aqueduct thence to Frankley near Birmingham.

The Silurian sequence of Rhayader has been described in great detail by Mr. H. Lapworth.* According to him the reservoirs in the Elan and Claerwen valleys are situated chiefly on the slates which form the Dyffryn Flag subdivision of the Gwastaden Group or Lower Llandovery rocks of the district. There are many natural sections and the works have opened up others.

* *Quart. Journ. Geol. Soc.*, vol. lvi (1900), p. 67.

The dam of the Dolymynach reservoir is being constructed on Mr. Cantrill. a grit bed underlying cleaved shales and forming a compressed anticline and syncline trending north-east and south-west, and traversed by two well-marked thrust-planes along which movement has taken place from the north-west. This grit appears to be part of the Cerig Gwynion Grits which immediately underlie the Dyffryn Flags and form the base of the local Lower Llandovery.

The aqueduct leaves the Carreg-ddu reservoir by a tunnel carried through the Dyffryn Flags of Craig-y-Foel, across the well-marked Abernant Fault and into the Caban Group or Upper Llandovery.

East of Elan Village the pipe-track passes into the Rhayader Pale Shales or Tarannon Beds, and continues in this subdivision as far as the western side of the Wye Valley south of Rhayader. It then descends the sequence into the Gwastaden or Lower Llandovery, the Caban Group having apparently been overlapped. The Gwastaden Group consists of various shaly, flaggy, and conglomeratic beds subdivided into several zones characterised by peculiar graptolites. The pipe-track gradually crosses these subdivisions and passes off the lowest at Gaufron, 2 miles east of Rhayader. It then enters the district occupied by the dark shales with grit-bands believed by Mr. Lapworth to be of Bala age. Of this district he remarks* that certain dark seams in the arenaceous rocks yield *Diplograptus foliaceus*, Murch., and other graptolites. Beyond this district of Nantmel we leave the ground examined by Mr. Lapworth.

East of the river Clywedog cleaved brown shales are introduced by a bold feature which crosses the district in such a way as to suggest that it is due to newer beds markedly unconformable to or faulted against the Ordovician, and the aqueduct is carried through this feature by the "Penybont Tunnel" into the Ithon Valley. The tip at the western end of the tunnel in Gwgan Hall Wood is composed of dark flags and shale, with pieces of conglomeratic rock; no fossils were observed, and there was nothing to show the exact source of the *débris*. Probably most if not all of this material came from the Ordovician beds. Surface exposures along the course of the tunnel show that the newer strata dip on the average in an easterly direction. These beds are shown on the Geological Survey map [old series, Sheet 56] as belonging to the Wenlock Series. But the brown and grey shales and sandstones forming the tip (presumably from the eastern part of the tunnel) south of Bryn-hyferth (= Brynrhyfedd on the old series map) being full of graptolites, some of these were collected by Prof. Watts and myself, and have been identified by Miss Ethel M. R. Wood, of Birmingham University. She reports as follows:—

* *Op. cit.*, p. 96

Mr. Cantrill.

"On tipat Bryn-byferth Farm [Six inch map, Radnor, 16 S.E.], 1½ miles north-west of Penybont Village, graptolites occur in great abundance on thin splintery brown shales. I have identified *Monograptus colonus*, Barr., *M. Nilssoni*, Barr., *M. bohemicus*, Barr., *Retiolites spinosus*, Wood. These graptolites are characteristic of the *M. Nilssoni* zone in the L. Ludlow shales, which occurs above the *M. vulgaris* zone and below that of *M. scanicus*. This zone is quite similar, both lithologically and paleontologically, to that in the Builth District, and also agrees closely with the same zone in the Long Mountain.

"In somewhat more flaggy beds at the same locality occur *M. colonus* in abundance, associated with one or two fragments of *M. bohemicus* and *M. Nilssoni*. These belong to the same zone as the above."

It thus appears that the Silurian beds here must be referred to the Lower Ludlow Shales and not to the Wenlock Series.

Roadside exposures at Tre-grugyn, at the supposed junction of the Ludlow and Wenlock north of Llanfihangel Rhyd Ithon yield graptolites, among which Miss Wood has identified *Retiolites spinosus*, and remarks that she has not found this hitherto outside the *M. Nilssoni* zone in the Lower Ludlow. This, together with the evidence of the graptolites from the Penybont Tunnel, makes it doubtful whether there is any foundation for the position of the Lower Ludlow base here.

Numerous exposures of the Ludlow beds occur thence to beyond Knighton. The Old Red Sandstone west of Brampton Bryan where crossed by the pipe-track is overspread with gravel, and the solid rock does not seem to have been exposed. East of Brampton Bryan gravel extends as far as Walford, beyond which the Silurian beds are more of the classical Shropshire type, and contain various bands of limestone. The Aymestry Limestone forms some fine cliffs on the west side of the Teme south of Downton. Some of the beds are full of *Pentamerus Knightii*. Beyond this point the pipe-track closely follows the top of the Aymestry Limestone. The Passage-beds into the Old Red at Ludlow do not seem to have been exposed, and east of the river Teme the pipe-track enters and continues for some distance in the lower beds of the Old Red Sandstone. It crosses the Ludlow series of Caynham Camp and revealed below the Aymestry Limestone some thickness of shales not shown on the map. (Sheet 55.)

The "Studley Tunnel" under the southern promontory of the Titterstone Clee Hill commences north of the village of Hope Baggot, in the Old Red Sandstone. From information supplied by Mr. J. McKie, the engineer in charge, it appears that the beds at first encountered consist of the ordinary red and green marls and soft shaly red sandstone; but at about 1400 feet the heading passed into harder beds of pebbly light-red coarse sandstone, the pebbles being chiefly of vein-quartz. This bed had not been pierced at the time of my visit. There is little doubt that this represents the Upper Old Red Sandstone, or at least the highest Brownstones of other districts, while the marls with cornstones which occupy the lower horizons and extend from Ludlow to the Wyre Forest Coalfield belong to the Lower Old Red. The eastern heading of the Tunnel was at the time of my

visit about 1100 feet in; it had passed from Old Red through the Carboniferous Limestone into Millstone Grit and possibly Coal Measures—various yellow and grey grit *débris*, together with clods, shales, and fireclays, occurring on the tip. If these latter belong to the Coal Measures, the lines on the map will need some little adjusting, as the Coal Measures are shown as forming only a capping at the top of the hill where crossed by the line of the tunnel.

Beyond Studley the aqueduct crosses the broad tract of Lower Old Red, extending from Clee Hill to the Wyre Forest. The Coal Measures of this latter coalfield where crossed by the pipe-track—from Malpass Wood to Hawkbatch Farm on the Severn—appear to consist of two groups: a lower, of variegated marls with yellow and green sandstone, in which the crop of a coal has since been cut through at Silligrove; and a higher group of grey and yellow sandstones with thin pyritous coals and one or more bands of *Spirorbis* limestone. The lower group has some likeness to the Old Hill Marls of South Staffordshire and the Etruria Marls of North Staffordshire; while the higher, as seen at Winwoods and Kingswood, and again at Woodhouse Farm near Button Oak, may represent the Halesowen Sandstones of the former district and the Newcastle-under-Lyme beds of the latter.

The junction of these Coal Measures with the Lower Old Red of Trimpley appears to be either a very sharp overfold or more probably a fault, the Old Red being thrust from the east over the Coal Measures. The lowest beds of the Trimpley anticline appear to be certain flaggy greyish-red beds and yellowish-grey tilestones which crop out at Trimpley Church and Littlegains. From these beds numerous fish-remains were obtained by G. E. Roberts,* who considered them to represent the uppermost Silurian or Passage-beds of other districts.

Beyond the Old Red Sandstone of Trimpley the Trias is entered and extends as far as Hagley, near Stourbridge. The sections call for no particular note. The so-called Lower Permian beds of the South Staffordshire Coalfield were then entered. The rocks consist of red and crimson marls, mottled blue, with some pale-red sandstone and occasional bands of conglomeratic cornstone. The presence of bands of *Spirorbis* limestone in similar beds at Sandwell and Hamstead Collieries on the east side of the coalfield had long been known, but no outcrops in the "Permian" ground to the south had previously been observed. The excavations for the pipe-trench have now exposed outcrops of such limestones at three different points between Hagley and Frankley. The first locality lies 100 yards west of Wassel Grove Lane at Hagley; the second is on the edge of Offinor Wood, north-north-east of the Fox Inn at Romsley. The third is at the terminal reservoir at Frankley, where the limestone contains the characteristic fossil. From information supplied by Mr. Fred. W. Macaulay,

* *Rocks of Worcestershire*, 1860, Chap. vii.

Mr. Cantrill, the engineer in charge, it appears that the limestone outcrop was met with in some excavations for the filter-beds at about 250 yards N. 20° W. from Frankleylodge Farm. The bed was about 1 foot or 1 foot 6 inches thick, the stone being rather rotten and much broken up. The position of this band is not far below the bottom of the "Permian" breccia as drawn on the map (Sheet 54 N.W.); and whether this latter is conformable or not to the red marls and sandstones, there is little doubt that the limestone here is higher than the other two bands, and that there are three distinct bands of *Spirorbis* limestone in these red rocks.

NOTES ON THE GOOLE AND MARSHLAND LIGHT RAILWAY.

BY W. GIBSON.

The Goole and Marshland Light Railway, now under construction, passes over the more elevated portions of the Isle of Axholme, and exposes some good sections of the solid rocks which are rarely to be seen in this part of Lincolnshire.

To the north of Haxey Village a cutting, one mile long and 30 to 40 feet deep, is being excavated in Keuper marls. These consist of red and green sandy marls, containing "skerries" and bands of red sandstone a few inches thick. Fibrous gypsum, in the form of isolated plates or in irregular bands from two inches to four inches thick, is developed throughout. The stratification is irregular, a feature common to the gypsiferous portions of the Keuper marls elsewhere.

The marls are overlain by a warpy silt 3 to 4 feet thick; the junction with the marls is sharp and even, and forms a line of demarcation for nearly the entire length of the section to near Haxey Village, where blown sand forms the surface-deposit. The warpy silt lies close to the 100 feet contour, and has the appearance of being of aqueous and not of æolian origin. If this is correct it implies a certain amount of elevation; but the relation of the warpy silt to the other superficial deposits of the district is not clear.

In making the foundations near the drain north of Haxey Station Mr. M. F. Glover, the engineer in charge of this section, proved sand for over 26 feet. A ferruginous band was passed through six feet below the surface.

Blown sand appears to occupy much of the surface passed over by the line from the north end of the cutting at Haxey to Epworth.

A cutting has just been commenced one half of a mile north-west of Epworth Church. The section exhibits Keuper marls of a very similar type to those of the Haxey cutting, but the bands of gypsum are slightly thicker.

Between Epworth and Crowle Town the line has not been laid out.

Crowle Hill, near Crowle Town, has been partly cut through from the north. Warpy sand 3 to 4 feet thick forms the surface of the section. This rests on Keuper marls containing thin

bands of gypsum, like those in the Haxey and Epworth cuttings. Mr. Gibson. The stratification is more evident, and a dip of 15 degrees east can be clearly made out. The north end of the section shows blown sand overlain by the talus from an old quarry through which the line passes.

No sandstones have been met with in any of the sections of sufficient hardness or thickness to form building stones. These evidently occur lower down in the sequence, for in the Reedness boring, which is on the line of strike of Crowle Hill, the sandy marls were 272 feet thick, after which sandstones were met with.*

North of Crowle Hill the line passes over warped land. As shown in the excavations for the telegraph posts the warp lies on peat and is nearly all of artificial origin.

Peat is being extensively dug for litter south of Reedness station. At this spot numerous stumps of trees, several standing erect, are exposed in the excavations for the line and station buildings. They are overlain by a thin layer of warp.

II. PETROGRAPHICAL WORK.

The material forwarded to the Petrographical department Dr. J. S. Flett. in London for examination and report during the year 1901, has to a very large extent been furnished by those areas of the Scottish Highlands which lie to the east and south of the Great Glen, and has consisted, as in former years, principally of metamorphic and intrusive rocks. The approaching publication of several sheets and descriptive memoirs from this region has rendered necessary the revision of the petrographical collections which have been made during the progress of the field work, and has suggested problems for special investigation. This seems, in consequence, to be a favourable opportunity to discuss some of the outstanding results of the study of the rocks of the Southern Highlands of Scotland.

The groundwork of this area is formed of masses of sedimentary rock, the age of which is at present uncertain, and these differ to an extraordinary degree in their state of metamorphism in the various sub-districts included in this extensive country. Omitting for the present all consideration of the rocks which form the narrow strip which is supposed to be of Arenig age, and which lies on the southern margin of the Highlands, and is apparently bounded by faults on both sides along most of its extent, we find among the Highland rocks some in which the metamorphism is no more advanced than in the greywackes or shales of the Southern Uplands. So little have they been affected by the earth movements and other agencies which induce metamorphism that they can hardly be distinguished from the Arenig (?) rocks of adjacent areas. In the finer shales the original bedding is so little obscured in some cases by the development of slaty cleavage that the geologist is at once impressed by the possibility that a

* "The Geology of parts of North Lincolnshire and South Yorkshire." *Mem. Geol. Surrey* (1890), p. 7.

Dr. J. S. Flett. careful search might reveal the presence of fossils. The grits are quite as little modified; the original clastic structures are perfect; the original clastic micas are visible in abundance; while cataclastic structures and new micas are surprisingly little in evidence. A re-examination of the Highland series in the vicinity of Aberfoyle has confirmed the opinion already formed by the field officers that the metamorphism in that quarter is of the most rudimentary kind.

Mr. J. B. Hill in his paper on the progressive metamorphism in the neighbourhood of Loch Awe* has described very similar rocks from that region, and in Banffshire, many miles to the north-east of this, Mr. Hinckman has observed on the headwaters of the Deveron (Sheet 85) grits and shales, which, though often indurated by the contact action of adjacent intrusive masses, have still their clastic characters very perfectly preserved.

Such areas of low metamorphism, however, are not usually extensive, the largest being probably that which stretches along the southern border of the Highlands from Cowal through Aberfoyle and Callander into Perthshire, where the rocks gradually assume that highly crystalline character which Mr. Barrow has described† in the regions drained by the rivers North Esk and South Esk, in Forfarshire. Throughout this tract the degree of metamorphism is low as a rule, though not everywhere the same. But as we pass northwards the metamorphism increases with great rapidity. There are cases in which, in little less than a mile as measured across the strike, coarse felspathic grits can be seen to pass through various intermediate conditions into granulitic quartzose gneisses in which clastic structures have been entirely obliterated. Most interesting to the student of metamorphism are sections such as may be observed near the Trossachs Pier on Loch Katrine, or on the west shore of Loch Lomond, near Inverbeg, where, in a single exposure, all stages in the passage of a grit into a foliated gneissose rock can be exemplified. In the forthcoming explanations of Sheets 38 and 55 the materials obtained from a study of such sections, and the conclusions they lead to, will be discussed in reference to the geology and structure of the districts in which they occur.

The great sedimentary series of the Southern Highlands—conglomerates, grits, greywackes, shales, limestones, and the problemetical "Green Beds,"—is penetrated by igneous intrusions, which, as regards their age and geological relations, fall naturally into two subdivisions. Of these one is the older and has preceded part, at least, of the movements to which the area has been subjected. They are, in consequence, foliated, though it is

* J. B. Hill. "On the Progressive Metamorphism of some Dalradian Sediments in the Region of Loch Awe," *Quart. Journ. Geol. Soc.*, vol. lv., p. 470, 1899.

† George Barrow. "On Silurian (?) Rocks in Forfarshire and Kincardineshire along the Highland Border," *Quart. Journ. Geol. Soc.*, vol. lvii., p. 328, 1901. "On an Intrusion of Muscovite-biotite Gneiss in the S. E. Highlands of Scotland, and its Accompanying Metamorphism," *Quart. Journ. Geol. Soc.*, vol. xlix., p. 330.

important to remember that, like the sediments they pierce, they vary much in degree of their metamorphism. Some are, in fact, gabbros, norites, peridotites, or granites, with their original minerals well preserved, and exhibit the characteristic structures of plutonic igneous masses. On the Deveron, in Banffshire, in the district already mentioned, where the sediments show so little alteration (Sheet 85), there are gabbros and serpentines which are indeed affected by the earth movements which resulted in the foliation of the area, but are still so little modified that their igneous structures are very well seen. As metamorphism advances they pass through flaser gabbros into epidiorites and hornblende-schists, and this last is the prevalent type of basic intrusive rock throughout the Southern Highlands. Dr. J. S. Flett.

The porphyritic andesitic basalts of the Loch Awe series as described by Mr. J. B. Hill are further examples of the perfect preservation of igneous structures in the rocks of this group.

It is not only in the degree of their metamorphism that great variations can be traced. In chemical composition they exhibit differences which are quite as great. As already stated, they are mostly rocks of basic affinities, epidiorites and hornblende-schists. With these occur peridotites and serpentines, with various kinds of talcose, actinolite-schists, which have developed from the shearing of ultra-basic masses. But acid gneisses, which correspond to biotite- and biotite-hornblende-granites are also known, as has been shown by Mr. Kynaston in the district around Dalmally, Argyllshire, and the passage from the hornblende-schists to the older granites and gneisses can now be bridged over almost completely.

Another feature worthy of mention is the presence of fine-grained and vesicular igneous rocks in association with others of the coarse-grained type which predominates.* In Sheet 85, on the Deveron, in Banffshire, Mr. Hinxman has mapped fine-grained vesicular hornblende-schists, the vesicles being filled with calcite. When the rock weathers it has quite a pumiceous aspect. It seems quite possible that these may be contemporaneous lava flows, but the very similar rocks from Loch Awe, Mr. J. B. Hill regards as intrusive. There can be no question that, as a whole, the hornblende-schists are intrusive sheets. This can often be proved by their transgressive junctions and their fine-grained chilled edges. Where the original structures can be traced they are those of slowly cooled masses. Occasionally they induce contact alteration in the sediments they break through. This, in most cases, amounts only to a slight induration, but on the Blackwater, in Sheet 85, a slate can be shown to pass at its contact with an intrusive mass of gabbro, epidiorite and serpentine, into a silvery mica-schist with large crystals of staurolite and andalusite. Such evidence of thermal alteration, however, is exceptional.

The rocks which are being mapped by the Geological Survey as "Green Beds" include a very great variety of petrographical

* See Mr. Kynaston's remarks, *Summary of Progress of the Geological Survey of the United Kingdom* for 1890, p. 33.

Dr. J. S. Flett. types. They are a group of sedimentary rocks characterised by the abundance of chlorite, epidote, or hornblende, and this gives them a green colour and a peculiar method of weathering. In the south-western part of the Southern Highlands, in Cowal, and on Loch Lomond, they are mostly chloritic and epidotic grits, and rarely contain hornblende. But the "Green Beds" of Central Perthshire, and of Forfarshire, are rich in hornblende and constitute a remarkable series of hornblende-schists of sedimentary origin. Mr. Cunningham Craig has paid special attention to the "Green Beds,"* and in the valley of the Tay, near Aberfeldy (Sheet 55), he has found that it is often a matter of some difficulty to distinguish between the intrusive hornblende-schists and those belonging to the "Green Bed" series. As a rule indications are not wanting which enable the field-geologist to discriminate between them. The "Green Beds" may be seen to pass gradually into sheared grits by increase in the proportion of quartzose detritus; the intrusive hornblende-schists show fine-grained chilled edges and the coarser central parts of the sheets have a quite distinctive appearance. But it is astonishing how closely the rocks of one group may resemble those of the other. Some "Green Beds" are fine-grained, well foliated hornblende-schists, with a little quartz and felspar, and not uncommonly biotite and garnet. There is very little to distinguish them from the finer epidiorites, but a careful search of the outcrops will usually show the presence of pebbly bands containing large, well-rounded grains of quartz, obviously clastic in origin. Where the metamorphism is greater the pebbles are drawn out into granulitic quartzose augen, and appear gradually to blend with the schist and become lost in the foliated matrix of the rock.

Of the older granites little that is new has this year been ascertained. They are well known to include types ranging from extremely acid muscovite-gneisses and pegmatites to biotite-gneisses such as that of Ben Vuroch, and are believed to have effected great contact metamorphism in certain districts.

During the year 1901 the principal area of the newer granites in Scotland to be submitted to microscopic examination was that of Ben Rinnes, in Elginshire, which proved to contain the usual association of biotite-granite, diorite and augite-diorite, with subsidiary masses and veins of muscovite-granite, aplite and muscovite-pegmatite. On the east side of Loch Lomond a mass of hypersthene-diorite, or hyperite, already known, has been further examined, and shows some interesting contact phenomena. At Netherly, near Rothes, Elginshire, a mass of diorite, one of the facies of the newer granite of Ben Rinnes, has converted the micaceous schists of the Moine series into cordierite-hornfels, with andalusite, sillimanite, and garnet.

The dyke rocks of the Southern Highlands, associated with the newer granites, have received much attention and study, both in the field and with the microscope. Their great abun-

**Summary of Progress of the Geological Survey of the United Kingdom for 1900*, p. 25.

clance and diversity makes them a peculiarly fascinating subject. Dr. J. S. Flott. Their relations to the newer granites are always sufficiently close to establish a community of origin, though there are cases in which they cut the granites, and others in which they are altered and hornfelsed by adjacent granitic intrusions. Two distinct series of dykes can be established—the porphyries (and porphyrites) and the lamprophyres. Space will not permit of a discussion of the classification of the dyke rocks as a whole, but a few remarks may be made on the most difficult group, the lamprophyres.

Owing partly to their inherent variety, partly to the great readiness with which they decompose, and partly to their propensity to develop distinct facies in different parts of their course, it is no easy matter to say exactly to what subdivision of the group any particular example is to be assigned. Their essential minerals, biotite, brown hornblende, orthoclase, and plagioclase are often all present in the same specimen, and may occur in any relative proportion. The classification at present in use is simple, and appears to be the most satisfactory that can be proposed, though admittedly there are individual occurrences which lie on the border line between the various groups. The dykes consisting principally of biotite and orthoclase are minettes; of biotite and plagioclase, kersantites; while those in which hornblende preponderates fall into the vogesites (orthoclase and hornblende), and the spessartites (plagioclase and hornblende). For rocks containing both biotite and hornblende there is a choice of terms: mica-vogesite or hornblende-minette, and mica-spessartite or hornblende-kersantite, the use of which will depend on whether hornblende or biotite is the dominant ferro-magnesian mineral. Thus, if the section contains orthoclase with hornblende and a subordinate amount of biotite, the last named may be regarded as an accessory mineral, and the designation employed would be mica-vogesite or mica-bearing vogesite.

The grouping adopted is, however, entirely artificial, and it should not be forgotten that a vogesite dyke may pass into minette or spessartite as it is traced along its course. A further difficulty arises from the rapid decomposition which characterises the lamprophyre group. They are often so charged with secondary carbonates that the determination of their felspar is impossible. For these and other reasons it is advisable to retain the generic designation "lamprophyre" to mark the outcrops as shown on the maps.

A word may be added regarding the term spessartite and the relations of the spessartites to the camptonites. As Rosenbusch has pointed out there are two series of lamprophyres, consisting essentially of plagioclase felspar and hornblende, which differ so greatly from one another in physical characters, chemical composition and geological affinities, that they cannot be united. The spessartites belong to the granitic-dioritic magmas, and are associated with vogesites, minettes, and kersantites. The camptonites are associated with alnöites, monchiquites, and

Dr. J. S. Flett, fourchites, and seem to have been mostly emitted from foyaite, essexite, and theralite magmas. The spessartites are rather of intermediate, the camptonites of highly basic character. The deep red-brown hornblende of the camptonites differs considerably from the paler, often greenish-brown hornblende of the spessartites, and while quartz is frequent in the latter, it is absent from the former. The augite of the camptonites is dark purplish-brown, of the spessartites mostly pale clear green. At present it cannot be said with certainty that typical camptonites do not occur in the Southern Highlands, as certainly some very basic hornblende bearing lamprophyres are known there, but if they do occur they are rare.

It will be noticed that according to the nomenclature here adopted the "camptonites" will be subdivided into the spessartites and camptonites, and the former are far the most common throughout Scotland.

In the report of this department for the year 1900, Mr. Teall has recorded the very important observation that in Assynt (Sutherlandshire), the dark coloured hornblendic lamprophyres are accompanied by a light coloured felspathic series which he calls "felsites." We have in fact a development of complementary rock suites, a melanocratic and a leucocratic group forming a diaschist-complex as defined by Brögger. It has long been known that in the Southern Highlands there are pale felspathic dykes which have been variously named felsites, orthofelsites, trachytes, etc. Their close relation to the lamprophyres has been noted by more than one of the field officers. They consist almost entirely of orthoclase, are often fine grained and frequently porphyritic. One point is of some importance as regards their origin, and that is that they often show the large corroded xenocrysts of quartz so common in lamprophyric rocks, while quartz is usually absent from the groundmass. It is in every way probable that we have here a leucocratic complementary series to the melanocratic lamprophyres, such as has already been shown to exist in Sutherlandshire.

A further interest has been lent to the study of the dyke rocks of the Scottish Highlands, during the past year, by Mr. Grant Wilson's discovery in Glen Finnan, Inverness-shire, of an occurrence of typical malchites (Rosenbusch). Though they lie outside the area with which we have been dealing in this Report, they are of sufficient interest to merit a brief description.

The malchite dyke rocks from Glen Finnan are grey and fine-grained, consisting of hornblende and plagioclase, never conspicuously porphyritic in the hand specimen, and bear a general resemblance to fine-grained diorites, though on the whole paler in colour than the majority of dioritic rocks. Many of them exhibit a parallel structure which in most cases is the result of fluxion; others are entirely massive.

Although consisting essentially of hornblende and plagioclase they contain as a rule more or less biotite, and this may so increase in quantity as to almost entirely replace the hornblende. A certain amount of orthoclase may be present, and

occasionally a very little quartz. The accessory minerals include **Dr. J. S. Flett.** sphene, apatite, magnetite and zircon, while epidote, chlorite, rutile, calcite and muscovite are secondary. One specimen contains orthite.

The hornblende is in small prisms often perfectly idiomorphic in transverse section, but usually elongated and irregularly terminated. Its colour is pale green to dark green, or dark bluish-green, and a very characteristic feature is the presence of minute dark enclosures, which have a regular orientation within the crystal. Often the crystals have a clear centre surrounded by one or two zones dark and turbid with these enclosures, while the external margins may be transparent and free from them.

The biotite is sometimes fox-brown, at other times greenish. It forms small irregular scales devoid of crystalline form. Biotite and hornblende are often aggregated together to form elongated clusters which may be conspicuous in the hand specimen, giving it a streaky appearance, suggesting foliation.

The felspar is mostly plagioclase, but in some of the slides there seems to be a certain amount of orthoclase. The prevailing felspar is perhaps andesine. Quartz in most cases is practically absent.

The structure is commonly panidiomorphic, all the minerals showing some idiomorphism, and this is especially true of the hornblende and the felspar. Some of the slides are really porphyritic, hornblende and plagioclase appearing in small idiomorphic phenocrysts in a groundmass of irregular smaller felspars. The phenocrysts are never large, and the porphyritic character is not obvious in the hand specimens.

Several of these dykes correspond exactly with certain types of malchite as described by Osann,* Chelius,† and Rosenbusch.‡ Others show not unimportant divergence from the original types. A description of these may be conveniently reserved till the mapping of their area of distribution is more advanced, and more is known about their varieties and mode of occurrence.

III. CHEMICAL WORK.

During the first half-year analyses of rocks and minerals for **Dr. W. Pollard.** officers in the field and for the Petrographical Department were made. In June Mr. E. G. Radley was appointed as general assistant in the laboratory. During July and August various analyses were made amongst which might be mentioned a rottenstone and the unaltered limestone from which it is derived, for Mr. Cantrill; a coal from the Colonial Office, and a coal seam which passes laterally into dolomite, for

* Osann, A. *Ueber dioritische Ganggesteine im Odenwald*. Mitth. d. Grossh. Bad. Geol. Landesanst., 1892. II. p. 380.

† Chelius, C. "Das Granitmassiv des Melibocus und seine Ganggesteine." *Notizbl. Ver. f. Erkunde*, Darmstadt. 1892.

‡ Rosenbusch, H. *Mikroskopische Physiographie*, B. II., p. 448. 1896

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Mr. Strahan. In August, at Mr. Strahan's request, the chemist was sent to Swansea to confer with and receive instruction from Mr. C. A. Seyler, B.Sc., F.I.C., etc. (Public Analyst for the counties of Carmarthen, Glamorgan, Pembroke, and the Borough of Swansea, and District Agricultural Analyst for the county of Glamorgan), in connection with the analyses of coals from the South Wales Coalfield.

In October the analyses of these coals was commenced, and the first ten samples completed by the end of the year.

Owing to the increased demand on the part of the officers in the field and the Petrographical Department for chemical investigation, it has been found necessary to provide for a second time temporary accommodation sufficient for another worker. For this purpose the gallery leading to the chemical laboratory is to be fitted with a working bench, etc., where Dr. Flett hopes to be able to perform certain investigations in connection with petrological work, as the chemist and assistant are fully employed on problems involved by the mapping of the South Wales Coalfield.

In the following report the most interesting portions of the year's work in the laboratory will be found, together with a short account of the methods of analysis in use in connection with the coal investigation.

The sincere thanks of the Geological Survey are due to Mr. Seyler, for his kindness in assisting and advising on this investigation.

ANALYTICAL METHODS IN USE IN CONNECTION WITH THE EXAMINATION OF SOUTH WALES COALS.

The methods in use in connection with this investigation are given rather fully, as it is well known in coal analysis that slight variations in methods (especially in the determination of volatile matter) may produce considerable variations.

Most of these methods are practically the same as those recommended by the Commission on Coal Analysis of the American Chemical Society (*Journ. Am. Chem. Soc.*, 1899, vol. xxi., p. 1116).

Sampling.—The samples as received at the laboratory are packed in large biscuit tins which are enclosed in wooden boxes. The weight of the sample is about 20 to 30 lbs. and usually contains no pieces larger than a small orange. All pieces larger than a walnut are crushed in a small Marsden-Blake crusher. The sample is then thoroughly united and quartered in the usual way to about 5 to 10 lbs. This portion is again passed through the crusher, united and quartered to about $\frac{3}{4}$ lb. This is at once transferred to a stoppered bottle and subsequently ground in a coffee mill set fine. The powder is at once transferred to two stoppered bottles, one for analysis, the other being at once tied down and sealed in case it should be required for future reference. The rest of the coal is at once replaced in its tin and also tied down and sealed.

It should be mentioned that a small quantity (about 150 grammes) of the last quarterings not required for sample are passed through the mill immediately before the sample for analysis is ground, to remove any dust or remains of a former coal left in the mill. The amount of coal left in the mill which might be thought to influence the next sample ground is so small as to render it unnecessary to take the mill to pieces after each time of using. The mill has been taken to pieces several times and on no occasion has more than a gramme of coal been found in it. As at least 300 grammes of each sample go through the mill (not to mention the first 150 grammes alluded to above for cleaning purposes), it will be seen that no appreciable error could arise on this account.

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The sample in the condition in which it comes from the mill is used for moisture and volatile matter determinations. This will be alluded to as "coarse moist" coal. For other determinations some of this is ground in a mortar to pass the 50-hole sieve. Moisture is determined on this sample also, so that all results can be calculated to the "coarse moist coal."

Volatile matter is determined on the fine as well as the coarse. In most cases the same value is obtained. Should any appreciable difference be found, both are given.

It is a well-known fact that coal loses moisture when ground fine in a mortar. Many samples of this are given by the Commission on Coal Analysis of the American Chemical Society (*loc. cit.*). Some data obtained in this laboratory in connection with this are given under "Moisture" p. 74.

The sample for specific gravity determination is taken from the last quarterings not required for the analysis sample, and that portion only is used which passes the 8-hole and is retained on the 16-hole sieve. In some cases this sample contains considerably more moisture than the others, partly due no doubt to its not being so long exposed to the air before being bottled.

Moisture.—(Determined both on coarse, fine and specific gravity samples.)

One gramme of coal is heated in a Victor Myer bath (toluene being used) for one hour exactly. The temperature obtained is about 105°.

The coal is weighed off between clipped watch glasses, heated uncovered, covered immediately on removal from the bath and allowed to cool in a desiccator.* It is weighed about half-an-hour after its removal from the bath.

The coarse moist sample is also dried in vacuo with sulphuric acid pumice in a Hempel desiccator for twenty-four hours. More moisture is often obtained by this method. (Cf. *Journ. Am. Chem. Soc., loc. cit.*)

The data obtained by drying at 105° for one hour are, however, always used in calculating the analyses, as this is believed to be the method of determination most frequently employed.

* Sulphuric acid pumice is used in all desiccators in this investigation.

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Duplicates (by the same method) should agree within .1 per cent.

The following table gives moistures determined on different samples at 105°, and on the "coarse moist" coal in vacuo with sulphuric acid:—

One Hour at 105°.				24 Hours Vacuo with Sulphuric Acid in Hempel Desiccator.
Sample No.	Sp. Gr. Sample.	Coarse Moist.	Fine 50 Hole.	Coarse Moist.
1	1.41	1.50	1.22	1.59
2	2.47	1.97	1.90	2.22
3	2.04	1.93	1.66	2.00
4	2.72	2.17	1.97	2.47
5	2.70	2.76	2.39	2.82
6	.80	.87	.86	.82
7	1.55	1.58	1.10	1.61
8	1.10	1.12	1.14	1.10
9	2.48	2.12	1.73	2.16
10	1.79	2.13	1.79	2.08

The above figures represent the mean of two or more determinations.

Volatile Matter.—One gramme of coal is heated in a platinum crucible with well fitting cover, supported on a platinum triangle over a bunsen giving a flame of 20cm. high for seven minutes exactly.

Bottom of crucible 8cm. above mouth of burner. Gas pressure 50mm. of water.

The dimensions of the crucible employed are—Height, 40mm.; diameter at base, 24mm.; at top, 34mm., capsule cover.

A cylinder of clay or asbestos board of about 12cm. diameter should be used to prevent draughts from influencing the flame.

Loss of weight—Moisture = volatile matter.

Duplicates should agree within

.15% on coals containing up to 15% of volatile matter.
.30% " " " over 15% " " "

It should be borne in mind that to some extent at least the value found for volatile matter depends on the size of crucible, tightness of cover, strength of flame, etc. It is therefore important in making this determination to keep as closely as possible to definite conditions in order that the figures found for various coals should be comparable.

The method of Meade and Attix (*Journ. Am. Chem. Soc.*, 1899, vol. xxi., p. 1137) of heating a second time under identical conditions, and subtracting the second loss from the first is being tried, but as yet sufficient data are not available for comment.

Ash.—As the main importance of knowing the exact amount of ash in a coal is to get the amount of oxygen as near as possible, it has been considered best to estimate the ash left in the platinum boat from the carbon and hydrogen determination.

In some cases this agrees perfectly with the value obtained by Dr. W. Pollard. ashing in a muffle, whilst in others the results vary considerably.

This appears to be due to the fact that in the muffle there is less oxidation than in the combustion tube, as might be expected. This seems to be borne out by the fact that the "sulphur in ash" obtained from ash from muffle has (in every case where estimated) been found appreciably lower than the "sulphur in ash" from the boat.

It may also possibly be due to a slight extent to alkalis being partly driven off in the muffle, where the temperature is probably higher than in the boat.* This has, however, not as yet been investigated, but should opportunity subsequently occur, it will be looked into. This variation of ash obtained in the muffle and in the boat has frequently been observed and mentioned by chemists.

Duplicates (by the same method) should agree to within 1% up to about 4% of ash, and to within 2% above 4% of ash.

Fixed Carbonaceous Residue.—Obtained by subtracting ash, volatile matter and moisture from 100.

Total Sulphur.—The method of M. W. and J. Atkinson has been adopted with very slight alteration.

The following description of the method is taken from the report of the Commission on Coal Analysis of the American Chemical Society, 1899, vol. xxi., p. 1116. [See also *Journ. Soc. Chem. Ind.*, Mch. 29, 1886. *Journ. Iron and Steel Inst.*, No. 2, 1896.]

"One gramme of finely ground coke or coal is mixed thoroughly
"with five grammes of dry sodium carbonate spread evenly over the
"bottom of a flat or shallow platinum dish, and the latter placed
"on a rectangular rest made of clay pipe stems inside a muffle,
"which though hot is still black. The temperature of the muffle
"should be raised gradually during half an hour to clear cherry
"redness, and then kept at the latter temperature for 10 or 15
"minutes. The sodium carbonate should not sinter or fuse. The
"mass should not be stirred. When the carbon is burned,
"usually in about 45 minutes in all, cool, digest with 100 to 200cc.
"of warm water, allow to settle, decant through a filter, and wash
"twice by decantation, and then on the filter adding a few drops
"of a solution of sodium chloride if the residue tends to pass
"through the filter. The filtrate is acidified with 12cc. concentrated
"hydrochloric acid, and precipitated with barium chloride."

To avoid any possibility of all the sulphur not being oxidised to sulphate before acidifying, it has been thought advisable to add a little bromine water (about 15cc.) before the addition of the hydrochloric acid. It has also been found necessary to heat in the muffle longer than 45 minutes to burn off all the carbon.

* It is well known that in the determination of ash in plants, potash is not infrequently lost by volatilisation, unless great care is used in the ashing and the temperature kept sufficiently low.

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With these slight deviations the method has been strictly adhered to with most satisfactory results.

The muffle used is a Fletcher, No. 461 (heated by gas). Blind experiments with sodium carbonate have frequently been made, both simultaneously with and separately from sulphur determinations, and in no case has sulphur been found to be absorbed from the gas. It is always necessary to test the reagents used for sulphur, and if found, to apply the correction, as it frequently happens that small quantities of sulphur (which in some cases might be sufficient to give $\cdot 1\%$ in the coal) are to be found even in sodium carbonate "Puriss."

Duplicates should agree within $\cdot 1\%$.

Sulphur in ash.—This is obtained from the ash from the platinum boat after combustion. The ash is evaporated with hydrochloric acid to dryness, taken up with hydrochloric acid and hot water, solution filtered, and the sulphate precipitated with barium chloride in the usual way. The amount of sulphur obtained here subtracted from the "total sulphur," gives "combustible sulphur."

Nitrogen.—Kjeldahl's method has so far been exclusively used, although it is proposed to do a certain number by combustion with soda lime for the sake of comparison. 1 gramme of coal is heated with 20cc. concentrated sulphuric acid, 8 grammes dry potassium sulphate, and a bead of mercury till colourless. Allow to cool, and pour into a flask of about 1000cc. capacity, containing about 200cc. water, rinse out, etc., and when cold add 80cc. of a 50% solution of sodium hydrate, and 20cc. of a 4% solution of potassium sulphide. Distil (using a good splash head) collecting distillate in 20cc. $\frac{n}{s}$ acid. Titrate back $\frac{n}{s}$ or $\frac{n}{s}$ alkali. Indicator Methyl orange.

The mercury (and hence potassium sulphide) may be omitted [Lunge, *Chem. Techn. Untersuchungsmethoden*, 4th edn., Vol. I., p. 228]; in fact, in the determinations made so far one nitrogen estimation has been made with, and one without, the mercury, the only difference observed being that the one with the mercury becomes colourless sooner than that with potassium sulphate only.

Blind experiments should be made, and if necessary a correction applied.

Duplicates to agree to within $\cdot 1\%$.

Carbon and Hydrogen, Ash.—Jena glass combustion tubes about 110cm. long and 12 to 15mm. internal diameter are used.

They are filled as follows:—

Copper oxide roll 6 to 8cm.
Space for boat 16 to 20cm.
Copper oxide from wire, not too coarse, about 50cm.
Lead chromate pumice 8cm.
Silver spiral 7cm.

The furnace used is a Fletcher combustion furnace, No. 2 pattern, 36 inches long. The boat is of platinum, 10cm. long. The purifying train (one for air and one for oxygen, with a three-

way tap, so that the gas can be changed at once) consists of an Dr. W. Emmerling's absorption tube, filled with pumice about the size Pollard. of peas, which is freshly drenched with 1 in 2 potash before each combustion 35 to 40cm. long, 20mm. internal diameter. Two wash-bottles, the first with potash the second sulphuric acid, followed by two large U-tubes with pumice saturated with concentrated sulphuric acid. (The pumice should be drenched with sulphuric and ignited in a muffle to expel chlorides, etc.) Between the three-way tap and the combustion tube a small sulphuric acid wash-bottle is placed (so that the rapidity of the gas current can be easily watched), followed by a small mercury trap.

For the collection of water a U-tube, filled with sulphuric acid pumice, is used. Before each combustion this tube is filled with concentrated sulphuric overnight, and the acid drained off immediately before weighing.

Geissler bulbs are used for absorbing the CO_2 with a drying tube 8cm. long, filled with freshly-crushed potash. A small U-tube, with sulphuric acid pumice, is used after the bulbs, to absorb any moisture that might be carried over. This tube, however, seldom gains more than a milligramme. Finally a protecting tube of sulphuric acid pumice. It is scarcely necessary to say that the bulbs and solid potash tube are refilled before each combustion.

Although it is unnecessary to go into details about the combustion, the following points may be worth mentioning.

The boat should contain as nearly as possible .5 gramme of coal (when dried). This has been found the most convenient amount to work with for accuracy. The fine-powdered coal (50-hole sample) should be used. The boat and coal should be dried at 105° for one hour exactly, cooled, and weighed in a stoppered tube immediately before required.

When the boat is placed in the combustion tube, it is best to rest it on a strip of platinum foil, to prevent it from adhering to the tube or from picking up any fragments of copper oxide.

Before commencing to heat the boat, the copper oxide must be at a bright red heat, the silver spiral and copper roll at a fair red heat, the lead chromate at a dull red heat. When these have been got to the required temperature, the boat is gradually heated (commencing at the copper roll end) in a gentle air current, until the volatile matter is practically all off; the oxygen is then turned on, and the combustion completed in the usual manner.

Duplicates should agree within

Hydrogen	.1%
Carbon	.2%

It is of the greatest importance that the copper oxide be hot enough before the boat is heated at all, as presumably methane would be amongst the first of the volatile products to come off; and it is well known that this gas requires a high temperature for complete combustion.

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In two combustions made recently, there seemed some reason to suspect that methane had escaped combustion, as the difference between the carbon and hydrogen of the lower to the higher result gave the ratios of

$$C : H = 1 : 3.5 \text{ and } 1 : 3.8$$

whilst the ash in each case agreed.

On repeating these, concordant results with the higher value were obtained. Another source of error, when duplicates agree in the hydrogen but not in the carbon, may be due to all the carbon not being combusted, a little remaining with the ash. This has been found to occur on more than one occasion, in each case the coal having a high caking power and considerable ash (over 5%). It was owing to this that a boat 10cm. long is now used instead of one of the usual size, as the half-gramme of coal can be spread out into a very thin layer, thus reducing the chance of incomplete combustion. The following is an example of the error just described.

A boat 5cm. was used, and the caking power of the coal was about 45.

	I.	II.	III.
C	79.72	79.97	80.13
H	4.75	4.76	4.82
Ash	8.38	8.12	7.98

It will be seen that the hydrogens all agree to within .1%, whilst the carbons are varying considerably. Nos. 2 and 3 are within the limit allowed of .2%, but No. 1 is too low. On comparing the ashes, it is seen that the difference of Nos. 1 and 2 to 3 are .40 and .14 higher respectively, whilst the carbons of 1 and 2 are respectively

.41 and .16.

Assuming the ash of No. 3 to be nearer the correct amount—the ash was nearly white, whilst 1 and 2 were grey—and subtract the ash of No. 3 from Nos. 1 and 2, adding the difference to the carbon, we get for the carbon

80.12 80.11 80.13.

It has been suggested that one cause of low carbon results might be due to some carbon monoxide escaping combustion to dioxide. At Mr. Seyler's suggestion, a small flask, containing a dilute solution of sodium palladium chloride, was placed behind the protecting U-tube, so that all gases escaping from the combustion and not previously absorbed by the U-tube and potash bulbs, must pass through this solution, and render it possible to detect monoxide. On no occasion has the solution been darkened, in spite of one or two low carbon determinations, which could only be explained—as the hydrogens and ashes agreed—by assuming a leak had occurred, although none had been detected, or from some other cause unknown.

One or two other possible causes of error in coal combustion may be briefly alluded to. The carbon percentage may be affected to a marked extent by the way in which moisture is determined. If the moisture value obtained by drying in vacuo

over sulphuric acid more nearly represents the true moisture than the value obtained by drying at 105° for one hour, in certain cases the carbon may easily be a few tenths of a per cent. out. All coals analysed in this laboratory have moisture determinations done by both methods, but the value obtained by drying at 105° for one hour is exclusively used in calculating results, as this is the method more usually employed. The carbon, hydrogen, and ash are calculated first on the dry coal, and subsequently from these figures on to the "moist coarse" coal and dry ash and sulphur-free coal. The following example illustrates an error of the kind described:—

Moisture at 105° one hour	2.17%
" vacuo sulphuric acid	2.47%
Carbon on dry coal	82.80%
Calculated on to the "coarse moist" coal	
by moisture at 105°	81.00% Carbon
by moisture in vacuo	80.76% "

giving a difference of .24% on the carbon, which is outside the limit within which duplicates should agree.

This may be an exceptional case, as such a large difference as .3% in the moisture determined by the two methods is not often found. Where, however, coals rich in moisture have to be dealt with, it may be of importance to use both methods of moisture determination.

Two more sources of error will be just mentioned: first, the presence of carbonates in the coal, and, secondly, the error due to pyrites. A discussion on the latter will be found in the Report of the Coal Analysis Commission of the American Chemical Society (*loc. cit.*).

In calculating the composition of coals in this laboratory no correction has been applied for either of these errors, as, in connection with the pyrites, it is impossible to say whether the sulphur may not, at any rate, partly be in combination in the coal.

Caking Power.—The platinum crucible used for this determination has the following dimensions:—

Diameter at top 42mm., at base 30mm.
Height 50mm. Capsule cover.

The coal is powdered to pass the 50-hole sieve; sand to pass the 40-hole and stay on the 50-hole sieve. The coal and sand are mixed in varying proportions, but so that the total weight of the two used for an experiment always is the same; 25 grammes being the weight used.

The charge having been placed in the crucible, it is heated exactly as for "volatile matter" determinations, allowed to cool, and when cold the cake is removed, placed on a flat surface, and a 500-gramme weight cautiously placed on the cake. When the cake just crushes the caking power is reached.

The caking power is expressed as the weight of sand required per weight of coal.

Thus:	Caking Power =	4	Sand.	Coal.
		9	20.0	5.0
		24	22.5	2.5
			24.0	1.0

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The test is a rough one, and not capable of great accuracy.

Specific Gravity.—Estimated on about 5 grammes of the sample specially set aside for this determination, in a specific gravity bottle. Air is removed by an air pump.

Moisture and ash determinations as made on this sample was to be able to correct to dry and dry ash-free coal.

The correction for ash is made by deducting .01 from the specific gravity for each 1% of ash found.

The ash on this sample is determined in the muffle.

The results obtained are tabulated thus :—

PROXIMATE ANALYSIS.

Moisture	}	Given on (1) moist coal ; (2) dry ash-free coal.
Volatile matter.		
Fixed carbonaceous residue		
Ash		
Total	-	- 100.00

ULTIMATE ANALYSIS.

Carbon	}	Given on (1) moist coal ; (2) dry coal ; and (3) dry, sulphur and ash-free coal.
Hydrogen		
Oxygen		
Nitrogen		
Combustible sulphur		
Ash		
Moisture		
Total	-	- 100.00

Sulphur in ash
Total sulphur
Caking power
Specific gravity

ROTTENSTONE FROM SOUTH WALES.

The following analyses were made for Mr. Cantrill, to ascertain, if possible, what occurred in the conversion of the black limestone to Rottenstone.

For this purpose bulk analyses of the three samples were made, together with analyses of the residue obtained by treatment with dilute hydrochloric acid and boiling for about three minutes.

Samples of the residue from 1 were examined under the microscope, and found to contain minute cubes and apparently spheres of pyrites, the spheres may only be coated with pyrites.

A sample of the coarser constituents of 3 obtained by washing, by decantation with water, showed no cubes. Spheres were there, but of an iron-red colour, presumably due to ferric oxide from the oxidation of the pyrites. After this residue had been boiled with dilute acids, the spheres were no longer visible, the red colour had disappeared, and all that remained seemed to consist of a micaceous mineral and some crypto-crystalline silica.

Dr. Flett has given the following description of the black limestone (sample 1):—
Dr. W. Pollard.

E 3401. BLACK LIMESTONE S.W. OF CWM HAPFES, GLYN Tawe, Tawe Valley.

“A fine-grained dark limestone without organic structures, and consisting of small irregular grains of calcite, the surface of which are coated with brown films of limonite or organic matter or both. A few very small cubes of pyrites and flakes of colourless mica are the only visible impurities. There is no detrital quartz, and the silica shown in the analysis must exist as a thin framework of chalcedonic character between the calcite grains.”

The following are the results obtained by analysis :—

1. Limestone which, on weathering, yields Rottenstone.
2. Inferior quality Rottenstone.
3. Best quality Rottenstone.

	1.	2.	3.
SiO ₂ - - -	16.50	70.87	80.82†
TiO ₂ - - -	.07	.55	.29
Al ₂ O ₃ - - -	1.25	9.78	5.82
Fe ₂ O ₃ * ‡	.50	4.61	3.79
CaO - - -	44.00	1.60	1.43
MgO - - -	.69	1.32	.88
CO ₂ - - -	34.86	.27	Not found
P ₂ O ₅ - - -	.36	1.39	1.36
FeS ₂	.32	Not found	Not found
Na ₂ O - - -	Trace	.56	.30
K ₂ O* - - -	.32	2.43	1.40
H ₂ O 105° - -	.17	2.18	1.27
H ₂ O above 105° + Organic Matter	1.31	4.62	2.82
TOTAL - -	100.35	100.18	100.18

* Traces of MnO and Li₂O in all three.
 † Less than 1% of colloid silica in No. 3.
 ‡ All Fe calculated as Fe₂O₃.
 || S in 1 mostly as pyrites but probably a little pyrrhotite. All calculated as pyrites.

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The percentage of insoluble residue (prepared by boiling in dilute hydrochloric acid, etc., and igniting)

= 18·75 85·18 88·65

and the composition of these residues, expressed in percentage of the residue—

	1	2	3
SiO ₂ - - - - -	88·14	83·20	91·17
TiO ₂ - - - - -	·39	·64	·33
Al ₂ O ₃ - - - - -	6·75	10·36	6·01
Fe ₂ O ₃ * - - - - -	2·58	1·92	·69
CaO - - - - -	·12	·23	·65
MgO - - - - -	·73	·89	·70
K ₂ O - - - - -	1·70	) Only estimated in bulk not in residue.	
Na ₂ O - - - - -	Trace.†		

* All iron calculated as Fe₂O₃. † = less than ·05 %.

The analysis of the second quality Rottenstone (No. 2) is not really comparable with Nos. 1 and 3. The much larger amount of alumina in the residue and the alkalis of the bulk, being so much higher than in No. 3, seem to point clearly to there being more elastic material (micaceous minerals are recognisable in all three samples under the microscope) than in the other specimens. It will, therefore, not be considered further in detail.

On the other hand, Nos. 1 and 3 are distinctly comparable. In the following table No. 1 has been re-calculated after elimination of all lime and carbonic acid, and as much magnesia as is required by the excess of carbonic acid; all moisture and organic matter and the pyrites calculated to Fe₂O₃. It should be remarked, in connection with No. 1, that no high accuracy can be placed on even the first decimal, as after elimination of the above-mentioned constituents (roughly 80%) the amount of original substance taken for analysis would be represented by about ·2 gramme.

In No. 3 lime, moisture and organic matter have been eliminated.

One hundred parts would therefore contain—

	1.	3.	Difference.
SiO ₂ - - - - -	84·03	85·47	1·44
TiO ₂ - - - - -	·36	·31	·05
Al ₂ O ₃ - - - - -	6·35	6·13	·22
Fe ₂ O ₃ - - - - -	3·61	4·00	·39
MgO - - - - -	2·19	·93	1·26
P ₂ O ₅ - - - - -	1·83	1·41	·42
Na ₂ O - - - - -	Trace.	·32	·32
K ₂ O - - - - -	1·63	1·43	·20

From these figures it will be seen that Nos. 3 and 1 are almost identical.

What has happened is that the carbonates have been ex- Dr. W. Pollard.
tracted from the Limestone by weathering, leaving behind the siliceous matter which makes "Rottenstone." It is also clear that nothing has been introduced during the process of weathering, nor has anything, except the carbonates and sulphur, been removed.

The value of the Rottenstone appears to be due to the high percentage of siliceous material in a fine state of division.

WEATHERING OF MAGNESIAN LIMESTONE.

During the summer of 1899, whilst the Jermyn Street front of this Museum was being renovated, the opportunity was taken of collecting several specimens of the stone, to see how it had been affected by half a century of London atmosphere.* Owing, however, to more important work having to be attended to, it was not possible to complete the examination till recently. An interesting paper has appeared recently by Mr. E. G. Clayton, F.I.C., "On an Incrustation from the Stone Gallery of St. Paul's Cathedral." [*Proc. Chem. Soc.*, vol. xvii., p. 201 (1901).]

This paper is of great interest in connection with Portland stone in London atmosphere.

The report on the selection of stone for the Houses of Parliament [By Charles Barry, H. T. De la Beche, William Smith and Charles H. Smith. London: 1839] should be referred to, as it was a similar stone to the one recommended that was used in this Museum. The stone used here was from North Anston, Yorks, and its composition is given as—

		Upper Bed.	Fourth Bed.	Lower or Eighth Bed.
† 1.	Calcium Carbonate - -	52·0	52·5	52·8
	Magnesium Carbonate -	45·2	44·7	44·4
	Oxide of Iron and earthy matter	2·0	2·1	2·1
	Moisture - - - -	·8	·7	·7
		—	—	—
		100·0	100·0	100·0
† 2.	Calcium Carbonate - -	-	54·89	55·37
	Magnesium Carbonate -	-	42·07	41·71
	Protoxide of Iron - -	-	·49	·73
	Peroxide of Iron - -	-	·24	—
	Protoxide of Manganese -	-	Trace	1·68
	Silica - - - -	-	·56	·92
	Water - - - -	-	·51	·45
		—	—	—
		98·76	100·86	

* The Museum was erected during 1848 to 1851. Sir James Penni-
thorne, Architect.

† 1. From "Lithology," by C. H. Smith, read at Royal Inst. Brit.
Architects, April 29th and June 3rd, 1844. Analyst, R. Phillips, F.R.S.

† 2. G. F. Harris, "British Building Stones," from *The Builder*, Nov.
20th, 1886, p. 754. Analysts, Ransome and Cooper.

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From these analyses it will be seen that the stone is as near a true Dolomite as possible, the ratio of lime to magnesia (mean of these five analyses) being 1:97.

The following are the main points observed in this examination. The stone facing S.W. was more weathered than that facing S.E., doubtless due to the S.W. winds being mostly wet, and to its being the prevailing wind (cf. Report, p. 4). It is impossible to give any exact figures as to the amount of stone which has been weathered, or has flaked off, but probably it is something between 1 and 3mm. This rough estimate was made possible by the fact that the stone contains occasional segregations of calcite crystals. These have stood the weather much better than the stone itself, and stood out wart fashion on the surface. Where the rain had fallen directly, the stone was rather less black than where it was sheltered. Only a trace of magnesium sulphate could be found on the exposed surfaces, whilst an appreciable amount was found where the stone was sheltered.

A microscopic section of a specimen that had been sheltered from the direct action of the rain was prepared, showing the surface in section, which Dr. Flett has described as follows:—

The following notes on the microscopic characters of specimens of the stone of which the Museum of Practical Geology is built, and of their weathered surfaces, are by Dr. J. S. Flett:—

The stone is a granular yellow dolomite consisting mostly of small rhombohedra, often rounded and slightly irregular in outline, but showing perfect crystalline form when occurring in cavities and veins. It contains many irregular-shaped pores, which are sometimes filled up with re-crystallised dolomite, and through the rock are scattered rounded patches, apparently concretionary. The blackened surface of the under part of the moulding from which the fragment was taken has been preserved, and is well seen in the section. It is covered with small crystals of gypsum, mostly in the form of monoclinic prisms and swallow-tailed twins. These form a layer mixed with black particles, probably sooty matter, and resting on a thin black film, beneath which the rock is unattacked. The average length of these crystals is about $\frac{1}{16}$ inch, and the thickness of the deposit, as preserved in the section, a little greater than this. Outside of the thin basal carbonaceous layer there is no dolomite, but only gypsum, which has, apparently, been formed by the evaporation of aqueous solutions of sulphate of lime, which have leached out of the stone. The black film upon the surface of the dolomite can be seen, where it is less opaque than usual, to consist of fibres of gypsum crossing irregularly and mixed with black particles, apparently carbonaceous.

This formation of calcium sulphate, or gypsum, on the surface of marbles and limestones in town is well known.

Sir A. Geikie has gone very thoroughly into this in connection with "Rock Weathering, Measured by the Decay of Tombstones" (*Geological Sketches at Home and Abroad*, MM. & Co., 1882, p. 182, and *Proc. Royal Soc. of Edinburgh*, 1880).

In 'Geological Sketches' a figure of the altered surface of a marble will be found, which had stood for eighty-seven years in Edinburgh. Dr. W. Pollard.

The black edge of gypsum and soot similar to that described by Dr. Flett in his account of the microscopic characters above, is very clearly shown.

In addition to this gypsum deposit on the stone of this museum, in one or two places sheltered from rain, small crystals, some as long as 3mm., were found. These occurred presumably where condensed moisture had evaporated. They were found to be magnesium sulphate.

What has occurred is that the sulphurous and sulphuric acids in the air have attacked the dolomite forming calcium and magnesium sulphates, and the latter being more soluble has to a great extent been leached out. This is entirely borne out by the following analysis. The sample was collected from the surface of the stone as scraped off by the masons in cleaning it. Hence a certain amount of unaltered stone is also in the sample.

The composition was found to be—

Ignited insoluble residue	-	-	-	5.2
Oxides of Iron and Alumina	-	-	-	1.4
Lime	-	-	-	26.9
Magnesia	-	-	-	9.5
Sulphur Trioxide	-	-	-	20.7
Carbon Dioxide	-	-	-	19.4
Water lost at 105°	-	-	-	1.8
„ „ between 105° and 150°	-	-	-	9.1
Water above 150° + organic matter	-	-	-	6.5
				<u>100.5</u>

If we assume the following molecules to be present (the magnesium sulphate was calculated from the amount of magnesia determined in a solution obtained by extracting with cold water) we get :-

CaSO ₄ ·2H ₂ O	-	-	-	-	41.7
MgSO ₄ ·7H ₂ O	-	-	-	-	4.0
CaCO ₃	-	-	-	-	22.2
MgCO ₃	-	-	-	-	18.5
*CaO	-	-	-	-	.9
*(FeAl) ₂ O ₃	-	-	-	-	1.4
Residue	-	-	-	-	5.2
Moisture and Organic Matter	-	-	-	-	6.6
					<u>100.5</u>

Comparing this with the five analyses quoted above, it will be seen that the iron oxide and earthy matter has greatly increased, owing to the leaching out of lime and magnesium sulphates by the action of rain and fog.

* The CaO and (FeAl)₂O₃ uncombined here are possibly combined with the silica of the residue and with traces of Cl and P₂O₅.

Dr. W.
Pollard.

In conclusion it must be stated that the alteration of the stone surface is to a great extent due to chemical causes, owing to the presence of sulphurous and sulphuric acids in the London atmosphere. These decompose the dolomite giving sulphates of lime and magnesia. The sulphate of magnesia, being a soluble compound, is to a great extent leached out and washed away by rain. The sulphate of lime, being a sparingly soluble compound, is leached out to a far smaller extent and tends to form a coating (with the soot, etc.) which helps to protect the stone. No doubt flaking or scaling play an important part in the weathering as well, but it is not possible here to calculate to what extent.

Suffice it to say that, with the exception of a few blocks which were of inferior quality and hence had decomposed to a greater extent, considering the time and conditions to which the stone had been exposed, the state was by no means unsatisfactory.

MINERALS FROM SKYE AND ROSS-SHIRE.

A black spinellid mineral, collected by Mr. Harker, was separated and analysed with the following results.

Mr. Harker gives the following account of its occurrence:—

"A black spinellid mineral from the peridotite group of the Cuillins. It occurs as small lustrous octahedra, making up practically the whole of certain seams, usually $\frac{1}{2}$ to 1 inch thick, in the banded dunite of a small glen a little south of Allt a' Chaoich (the 'Mad Burn') near Loch Seavaig. The analysis shows it to be a Picotite. There are hitherto no analyses of this mineral from Britain."

SiO ₂	-	-	1.19			
TiO ₂	-	-	.34			
Al ₂ O ₃	-	-	46.54	-	-	.4554
Fe ₂ O ₃	-	-	6.01	-	-	.0376
Cr ₂ O ₃	-	-	17.55	-	-	.1153
FeO	-	-	10.10	-	-	.1403
MnO	-	-	Trace			
(CoNi)O	-	-	.24			
CaO	-	-	.43	-	-	.0077
MgO	-	-	18.35	-	-	.4547
Total	-	-	<u>100.75</u>			

Omitting Silica, Titanic acid, Manganese and Oxides of Cobalt and Nickel, the ratio of RO : R₂O₃ works out to .6027 : .6083
or 1 : 1.01

The following is an analysis of the felspathic constituent of a Nepheline-Aegirine-Syenite-Pegmatite, a boulder from Coulmore, Ross-shire, collected by Mr. Hinxman.

*Portion of powder (separated by bromoform, diluted with xylene) of sp. gr. between 2.556 and 2.510.

* The powder was first treated with hydrochloric acid to remove nepheline.

				Mol. Ratios.	Dr. W. Pollard.
SiO ₂	-	-	-	63·84	1·0570
Al ₂ O ₃	-	-	-	18·87	·1846
*Fe ₂ O ₃	-	-	-	·68	·0042
CaO	-	-	-	·18	·0032
K ₂ O	-	-	-	14·76	·1530
Na ₂ O	-	-	-	1·23	·0198
Loss on ignition	-			·30	
Total				<u>99·86</u>	

* State of Oxidation not determined.

This would represent—

K ₂ Al ₂ Si ₆ O ₁₆	-	-	-	-	-	85·85
Na ₂ Al ₂ Si ₆ O ₁₆	-	-	-	-	-	10·43
						<u>96·28</u>
Unaccounted for	-	-	-	-	-	3·58
						<u>·86</u>

The portion unaccounted for being composed of—

SiO ₂	1·22	Al ₂ O ₃	1·20	Fe ₂ O ₃	·68	CaO	·18
Loss on ignition							·30

TERTIARY IGNEOUS ROCKS FROM SKYE.

Three more Tertiary igneous rocks from Skye have been Mr. Harker. analysed. They were collected by Mr. Harker, who furnishes the following descriptions of them :—

8062 is an example of the innumerable sheets of basic rock referred to in former reports as cutting in an inclined direction the gabbro of the Cuillin Hills. It is a normal dolerite, bearing no close resemblance in composition to the gabbro. The locality of the specimen is Loch a' Bhàsteir.

9250 and 8732. Two closely associated rocks, forming one of a group of composite intrusions at Druim na Criche, five and a half miles N.W. of Sligachan.

Each of these intrusions consist of two laccolitic masses in contact with one another ; the upper of an olivine dolerite (9250) with large porphyritic crystals of labradorite, the lower of a peculiar rock (8732) of more compact texture, which may be styled olivine andesite, its principal constituent minerals being oligoclase and olivine.

Dr. W.
Pollard.

The analyses are as follows :—

	8062	9250	8732
SiO ₂ - -	47·64	50·33	49·24
TiO ₂ - -	1·27	1·81	1·34
Al ₂ O ₃ - -	14·16	19·97	15·84
Fe ₂ O ₃ - -	5·18	2·81	6·09
Cr ₂ O ₃ - -	Trace	Trace	Trace
FeO - -	7·96	6·23	7·18
MnO - -	·33	·17	·29
(CoNi)O - -	Trace	Trace ?	Trace
CaO - -	11·71	8·03	5·26
BaO - -	Not found	·06	·09
SrO - -	Not looked for	Trace	Trace
MgO - -	7·38	3·24	3·02
K ₂ O - -	·71	1·19	2·10
Na ₂ O - -	2·38	4·30	5·21
P ₂ O ₅ - -	·09	·17	1·47
F - -	Not looked for	Not looked for	·18
S - -	·03	Not found	·03
H ₂ O at 105°	·19	·87	1·08
H ₂ O above 105°	1·44	·99	1·61
Total.	100·47	100·17	100·53

Less O for F ·07

100·46

ROCK FROM NEWLYN, CORNWALL.

Dr. Flett.

The following specimen, E3424, was collected by Mr. Clement Reid. The locality given is "Gwavas Quarry, near Newlyn Cornwall, 1° 35' 8", 6° 74' S.W. Thick Sill (about 80'). Specimen from near the middle of the sill, and from the centre of a newly-broken block." Dr. Flett has examined the slice and gives the following description :—

E.3424. Gwavas Quarry, Newlyn, Cornwall.

Under the microscope this rock consists of actinolitic and tufted hornblende in small radiate groups of green needles, rather strongly pleochroic, and felspar, mostly plagioclase, but partly also untwinned alkali felspar. Much of the felspar is in large fairly idiomorphic crystals surrounded by smaller grains of irregular shape, so that the rock has a distinctly porphyritic character. According to the angles of symmetrical extinction the plagioclase is mostly an acid andesine. Grains of untwinned or simply twinned felspar (orthoclase or albite) are frequent in the groundmass surrounding the phenocrysts. In the larger nests and patches of actinolite there is a small amount of water-clear untwinned or simply twinned felspar which is probably albite. Iron oxides, leucoxene, and a few scales of biotite are the other ingredients. The actinolite may be regarded as having all formed from pyroxene, though no trace of the original outlines of this mineral can be found, and the clear albite appears also to be of new formation.

The analysis shows that the rock belongs really to the augite andesites or Dr. Flett. augite porphyrites. It contains too much silica and alkalis, too little lime and magnesia for a diabase. Even if all the lime is supposed to be present in the felspar (which cannot be the case as some is required for the actinolite) the ratio of lime to soda 3.71 to 6.52 would indicate a felspar of the oligoclase group. The original plagioclase is probably somewhat more basic than this (andesine), the rest of the soda being taken up in the albite and to a small extent in the orthoclase.

Sp. gr. 2.80 at 19°.						
SiO ₂	-	-	-	-	-	59.84
TiO ₂	-	-	-	-	-	.64
Al ₂ O ₃	-	-	-	-	-	15.71
Fe ₂ O ₃	-	-	-	-	-	1.68
FeO	-	-	-	-	-	7.03
MnO	-	-	-	-	-	.12
CaO	-	-	-	-	-	3.71
MgO	-	-	-	-	-	1.37
K ₂ O	-	-	-	-	-	2.76
Na ₂ O	-	-	-	-	-	6.52
S	-	-	-	-	-	.10
P ₂ O ₅	-	-	-	-	-	.20
H ₂ O 105°	-	-	-	-	-	.14
H ₂ O above 105°	-	-	-	-	-	.31
Total	-	-	-	-	-	<u>100.13</u>

Dr. W.
Pollard.

BaO and Li₂O not found.

PSEUDOGAYLUSSITE FROM THE CLYDE.

Note on Crystals from the Clyde, analysed by Dr. Pollard.* Dr. Flett.

These crystals were obtained a few years ago by a dredging steamer engaged in deepening the channel of the Clyde near Helensburgh. They are dark brown in colour, resinous, transparent only in thin splinters, with a yellow streak and powder, no cleavage, and hardness about 3. The commonest are long prisms pointed at both ends, but without crystalline faces. The largest measures $5\frac{1}{2}$ by $\frac{3}{4}$ inch. In transverse section these prisms are squarish or rhombic, but the angles vary considerably, and the roughness and rounded character of the faces do not allow of accurate measurements. On the best specimens small triangular facets cover the surfaces, their apices being directed from the edges towards the centres of the faces. The analyses show that they are impure carbonate of lime, the colouring matter being apparently organic, and the low specific gravity a consequence of a slightly porous structure. Microscopic sections showed that they have a distinctly zonal structure, and consist of little spherulites of fibrous calcite with occasional layers of parallel fibres between the spherulites and on the surface of the crystals.†

* Extracted from a paper read by Dr. Flett at the meeting of the British Association at Glasgow, September, 1901.

† For a full description of these crystals with an analysis, see Ch. O. Trechmann, "Ueber einen Fund von Ausgezeichneten Pseudogaylussit (=Thinolith=Jarowit) Krystallen." *Zeitschrift für Krystallographie* xxxv., 1901.

Dr. Flett.

Another mode of occurrence is in groups radiating from a centre. These may consist of as many as 40 or 50 individuals. The component crystals are smaller than in the previous cases, and have the barleycorn form of the well-known pseudogaylussite from Sangerhausen. The surface markings are similar to those described, but often the surface is honeycombed as if by corrosion. For specimens of these I am indebted to Mr. Renwick, Secretary of the Glasgow Geological Society.

Crystals of pseudogaylussite were obtained in excavations for the Jarrow Docks in 1857, and have been described by Professor Miers under the name of Jarrowite.* He agrees with Descloiseaux, Williams, and Dana that they are in all probability pseudomorphs after celestite. In this case tests for barium and strontium gave negative results, and a large clay nodule full of these crystals, forwarded by Mr. Renwick, proved to consist of carbonates of lime and iron mixed with clay, and did not contain strontium in determinable quantity.

Dr. W.
Pollard.

The crystals (from the Clyde) of pseudogaylussite which were analysed in this laboratory were sent to Mr. Rudler by Mr. John Paton, of Glasgow.

The analysis gave the following values:—

CaO	-	-	-	-	-	47.93
MgO	.	.	.	.	.	4.21
CO ₂	-	-	.	-	-	39.91
P ₂ O ₅	-	-	.	-	-	2.23
Loss at 105°	-	-	-	-	-	3.13
Loss above 105° (to ignition)	-	-	-	-	-	2.81 = Water and organic matter.
Residue insol. dil. HCl.	-	-	-	-	-	.11
						<u>100.33</u>

Traces of iron, manganese, chlorine, and sulphate also found.

No nitrogen found. Carbon of organic matter about 1.2%. Calculating as carbonates and phosphates,

Ca ₃ (PO ₄) ₂	-	-	-	4.87
CaCO ₃	-	-	-	80.88
MgCO ₃	-	-	-	8.28
MgO	-	-	-	.25 not accounted for.
				<u>94.28</u>

The specific gravity was found to be

On a crystal fragment	2.55	} at 23°
Powder in pyknometer	2.57	

Dr. C. O. Trechmann [*Zeitschrift für Krystallographie*, xxxv., p. 283, 1901] found

2.575 at 18.5° C. in coarse powder,
2.602 at 16.5° C. in fine powder,

for some crystals from the same locality.

* "On some British Pseudomorphs," by Prof. H. A. Miers, *Mineralogical Magazine*, 1897, xi., p. 264.

The composition of these are quoted below, for comparison with those analysed here:—

			Dr. C. O. Trechmann.	M.P.G.
$\text{Ca}_3(\text{PO}_4)_2$	-	-	5.52	4.87
CaCO_3	-	-	83.52	80.88
MgCO_3	-	-	9.03	8.28

This appears to show that the composition of the different crystals may vary, but the agreement is as close as may reasonably be expected in the case of pseudomorphs of this nature.

IV. PALÆONTOLOGICAL WORK.

The ordinary duties of the Palæontological Department in relation to the maintenance of the collection of fossils in the Museum of Practical Geology, and the detailed work necessitated in the registration and determination of the fossils received from the officers in the field and otherwise, although making the first, and a large, demand upon the time of the officers, call for little notice in this place. Some 800 new specimens have been added to the collection already in the Museum, and a large amount of revision has been accomplished, necessitating in some instances a rearrangement of the cases.

The large series of Echinodermata and Phyllocarida from Palæozoic formations, and the plants from the Inferior Oolite and other Jurassic strata, have been revised by Mr. H. A. Allen, who has taken advantage of this opportunity to prepare a catalogue of all the figured and type specimens in the first two of these groups, which this institution possesses, thus continuing the very useful piece of work begun some two years ago (*see Appendix, p. 200*). A similar catalogue of the Pliocene and Pleistocene figured specimens was prepared by the same officer early in the year, but, being ready, it was deemed expedient to publish it in the Appendix of the *Summary of Progress* for 1900.

The Carboniferous Cephalopoda, contained in the Museum cases, have undergone a similar revision by Dr. F. L. Kitchin, whose time has been largely occupied during this year with the determination of the large series of fossils collected by Mr. G. W. Lamplugh from the trial borings at Brabourne and Penshurst, as well as from the shaft at Dover. Dr. Kitchin has paid several visits to Dover in order to watch the progress of the shaft being sunk through the Jurassic strata, and has himself obtained representative collections of the fossils from the various horizons passed through.

The examination of the Devonian fossils collected by Mr. W. A. E. Ussher, and mentioned in last year's *Summary of Progress*, has been completed, and a preliminary report prepared. The occurrence at certain localities in the neighbourhood of Looe, and at other places in the Torquay promontory, of such fossils

Mr. E. T.
Newton.

as *Spirifera primæva*, *Orthotetes hipparionyx*, and *Pleurodictyum problematicum*, and the further recognition at still other places of *Strophomena latecosta* (= *Tropidoleptus rhenanus*), *Renssæleria strigiceps*, *Orthotetes hipparionyx*, and *Homalonotus*, seem to demonstrate that the Looe fauna occurs in the Torquay promontory. Certain of the characteristic fossils are likewise met with in the intermediate area. The fragmentary nature of the fossils makes the determination of the horizons somewhat uncertain; but Mr. Ussher has hopes of being able, by their means, to correlate the Devonian horizons in a large part of this difficult and disturbed district.

Three or four small sets of fossils were received from Mr. G. Barrow, from the promontory of Suishnish, between Loch Slapin and Loch Eishort, south of Broadford, Skye, where he was anxious to trace the upper limits of the Lower Lias, and possibly the base of the Middle Lias; but all the determinable fossils pointed to the beds belonging to the zone of *Ammonites Jamesoni*, and there was nothing that could be clearly referred to the Middle Lias at this locality.

A series of specimens of Cherts and other rocks from Alt nan Leac, Soay Sound, South Skye, have been examined; these were forwarded by Mr. C. T. Clough, who thought they might be of Cretaceous age. Some of the Cherts had been found *in situ*, others in the volcanic agglomerate of the district; and they resemble in appearance certain of those which had been discovered in Arran. Several slices were prepared, which showed, in the first place, that the rock *in situ* was similar to that in the agglomerate. In all these Cherts organisms are present, but they are much obscured by chalcedonic deposits. Sponge spicules seem to have been very abundant, but have become decomposed. Foraminifera are present, Textularian forms being most numerous, but *Globigerina* seems also to be represented. Some of the sections show fragments of Echinoderm plates and pieces of *Serpula*. These Cherts are unlike those from Arran, but support Mr. Clough's opinion of their Cretaceous age; it is thought, however, that these rocks have more the appearance of Greensand Cherts than of altered Chalk—an opinion which Dr. G. J. Hinde has been good enough to confirm.

A series of plants, collected some years ago from the Reading Beds in the Waterloo Brickyard, Reading, have been recently re-examined for the purposes of the Memoir on this district, written by the late J. H. Blake, and now being prepared for publication by Mr. H. W. Monckton. The following forms are believed to be present, but their determination can only be taken as approximately correct:—*Anemia subcretacea*, *Acer* sp., *Aralia* near to *looziana*, and *Laurus* resembling *L. Jovis*. There are likewise slender leaves like *Salix*; the base of a leaf like *Litsæa*; and a fragment with venation like *Viburnum*.

The following is a list of the specimens in the Museum of Practical Geology, figures of which have been published during the year:—

Palæontographical Society's volume for 1901 :—

By MISS ELLES and MISS WOOD :

- Didymograptus hirundo*, Salter.
 " *v-fractus* var. *volucer*, H. A. Nicholson.
 " *gibberulus*, Nicholson.
 " *deflexus*, n. sp.
 " *nanus*, Lapworth.

By DR. WHEELTON HIND :

- Leiopteria Thompsoni*, Portlock. Four specimens.
Actinopteria persulcata, McCoy. Three specimens.
Pteronites latus, McCoy.
Posidonomya Becheri, Bronn. Three specimens.

By R. H. TRAQUAIR :

- Elonichthys Aitkeni*, Traquair.

By H. WOODS :

- Trigonia scapha*, Agassiz.
Spondylus striatus, Sowerby.
 " *dutempleanus*, d'Orbigny.
Plicatula placunea, Lamarck.

Geological Magazine for 1901 :—

By H. A. ALLEN :

- Fouquea cambrensis*, n. sp.

V. MUSEUM OF PRACTICAL GEOLOGY.

Among the most notable donations is a large collection of polished Indian Agates, presented in the early part of the year by Mr. Lennox Boyd. Attention may also be called to a series of minerals from Victoria, presented by the Department of Mines through the Agent-General.

In view of the removal of the offices of the Geological Survey, on the expiration of the tenure of the adjacent premises in Jermyn Street in the course of the present year, measures have been taken to provide for the accommodation of the officers of the Survey in the Museum building. This has necessitated considerable alterations in the arrangement of the Museum. The collections of Pottery, Porcelain, Glass, Enamels and Mosaics have been removed, partly to the Victoria and Albert Museum at South Kensington, and partly to the Branch Museum at Bethnal Green. The space thus gained is being fitted up as a Petrographical Department, to which the rock specimens at present exhibited in a room on the Upper Gallery of the Museum, will shortly be transferred.

The contents of the two Model Rooms have also been removed, and such of the models as illustrate British Geology are now exhibited on the principal floor of the Museum, where space has been obtained for their display by the removal, to the Alexandra

Mr. F. W
Rudler.

Palace, of several cases of specimens illustrating the application of metals to various purposes of industry and art.

The Library has received many valuable additions during the year, and the collection of Geological Photographs has also been largely augmented. An extensive collection of the Maps and Sections of the Geological Survey of Great Britain and Ireland has been transferred from the Survey Office to the Library, where visitors desirous of consulting them will find them more convenient of access. Progress has been made in the work of removing from the Library those works which are not strictly Geological in character; and during the past year upwards of 7,000 volumes have been transferred to the Science Library of the Victoria and Albert Museum.

VI. MAPS, SECTIONS, AND MEMOIRS PREPARED AND PUBLISHED.

The following is a List of the Maps, Sections, and Memoirs issued by the Geological Survey of England and Wales during the past year:—

I.—MAPS.

One-inch Maps (New Series).

Sheets 261 and 262 (Bridgend), in one map. Two editions, with and without Drift. By R. H. TIDDEMAN and T. C. CANTRILL.

One-inch to four miles (Index) Map.

New Editions.

Sheets 8 and 11 revised. Sheet 12 reprinted.

Six-inch Reference Maps.

49 MS. coloured copies of six-inch sheets and quarter-sheets have been made from the field copies, and deposited in the Office for public reference. These are as follows:—

Berks.—9 N.W., N.E., S.W., S.E.; 16 S.W.
Brecon.—37 N.W., S.W.
Bucks.—41 N.E., S.W., S.E.; 46 N.W., N.E., S.W., S.E.
Carmarthen.—35 S.W.; 42 N.E., S.E.; 43 N.W., S.W.
Dorset.—21 S.E.; 31 S.W.; 40 S.W.
Glamorgan.—7 S.E.; 8; 14 N.E.; 15; 24.
Leicester.—18 N.W., N.E.; 19 S.W.; 27 S.W.; 33 N.E.; 38 N.E.
Oxford.—40 N.W., N.E., S.W., S.E.; 45 N.W., N.E., S.W., S.E.; 46 N.W., N.E., S.W., S.E.; 50 N.W., S.W.
Rutland.—4 N.E.
Wilts.—69.

II.—VERTICAL SECTIONS.

Three Sheets of Vertical Sections have been published.

Sheets 84 and 85 of Shafts in the South Wales Coalfield.
Sheet 86 of Shafts in the North Staffordshire Coalfield.

III.—MEMOIRS.

Summary of Progress of the Geological Survey of the United Kingdom " for 1900, pp. 221. Price 1s.

"Guide to the Geology of London." By W. WHITAKER. 6th edition. pp. 102. Price 1s.

List of Extra-official Publications.

ALLEN, H. A.—"On an Insect from the Coal-Measures of South Wales." *Geol. Mag.*, 1901, pp. 65-68.

GIBSON, W.—"On the Character of the Upper Coal-Measures of North Staffordshire, Denbighshire, South Staffordshire, and Nottinghamshire; and their Relation to the Productive Series." *Quart. Journ. Geol. Soc.*, vol. lvii., pp. 251-265.

HILL, J. B.—"On some Geological Structures in West Cornwall." *Trans. Royal Geol. Soc. Cornwall*, vol. xii., part vi.

NEWTON, E. T.—"British Pleistocene Fishes." *Geol. Mag.*, 1901, pp. 49-52.

———"Graptolites from Peru." *Geol. Mag.*, 1901, pp. 195-197.

STRAHAN, A.—"On the Passage of a Seam of Coal into a Seam of Dolomite." *Quart. Journ. Geol. Soc.*, vol. lvii., pp. 297-304.

———"An Abnormal Section of Chloritic Marl at Mupe Bay, Dorset." *Geol. Mag.*, 1901, pp. 319-321.

TIDDEMAN, R. H.—"On the Formation of Reef Knolls." *Geol. Mag.*, 1901, pp. 20-23.

USSHER, W. A. E.—"The Culm-measure types of Great Britain." *Trans. Inst. Mining Engineers*, vol. xvii.

WEDD, C. B.—"On the Corallian Rocks of St. Ives (Huntingdonshire) and Elsworth." *Quart. Journ. Geol. Soc.*, vol. lvii., pp. 73-83.

WOODWARD, H. B.—"Note on a Phosphatic Layer at the Base of the Inferior Oolite in Skye." (*Brit. Assoc.*) *Geol. Mag.*, 1901, pp. 519, 520.

II. SCOTLAND.

I. FIELD WORK.

Dr. Horne reports that in the northern district in charge of Mr. Gunn the work of the survey has been continued in the northern part of Inverness-shire and in the central and eastern parts of Ross-shire, as well as in a small portion of the county of Sutherland. Work was carried on in one-inch sheets 61, 71, 72, 83, 92, 93 and 102, and of these 71 and 92 are reported as completely surveyed.

1. NORTHERN DISTRICT—INVERNESS-SHIRE, ROSS-SHIRE AND SUTHERLANDSHIRE.

Mr. W. Gunn, District Geologist.

Mr. C. T. Clough	}	Geologists.
Mr. L. W. Hinxman		
Dr. C. B. Crampton		

The location of the staff was as follows:—

Mr. Clough worked in the parish of Glenelg in the western part of Inverness-shire: Mr. Hinxman in the Inverlael Forest and near Loch Garve in central Ross-shire, and in the northern part of Inverness-shire: Dr. Crampton in the Strathvaich and Inverlael Forests in central Ross-shire, and in the Strathrusdale district of East Ross-shire: Mr. Gunn in the Fannich and Strathvaich Forests of central Ross, in the Loch Broom district of the same county, and on the shores of the Dornoch Firth. The Assistant Director, Dr. Horne, completed the survey of some small portions of ground in the Fannich Forest.

METAMORPHIC ROCKS.

Mr. Clough.

Mr. Clough's work on the oldest rocks lay in two detached districts: (1) between the S.E. side of Loch Duich and the head of Glenelg; (2) near Inverguseran.

Glenelg.—In district (1) the oldest rocks belong to the Lewisian gneiss formation and the Moine schists. Among the members of the first formation were found marble, garnetiferous kyanite, biotite schist, hornblende schist, eclogite, and serpentine. Biotite schist forms most of the area between Balvraid and Loch Iain Mhic Aonghais. It is supposed to be an altered sediment of approximately the same age as the limestone, and it differs from the micaceous schist of the Moine formation in the same neighbourhood in various respects, particularly in containing thin streaks and lenticles of dark hornblende schist, and granulitic pale-grey quartz-felspar material, which has, perhaps, been formed from old pegmatites.

The Moine rocks occupy a considerably larger area than that of the Lewisian gneiss. In respect of composition they are generally divisible into two classes, one of more siliceous character than the other; but there are rocks of intermediate type, and it is not clear that all the rocks of one type are on one horizon.

The bands next to the Lewisian gneiss are in some places of the siliceous and in others of the more micaceous type. On the E. slope of Beinn Aoidhdailean is a thin strip of Lewisian gneiss, at the W. margin of which the Moine rocks are generally of the micaceous type; while on the E. margin, for about a mile along the strike, there is a band of siliceous schist. The phenomena might give the impression that we have here an unfolded succession of three rocks, in which the Lewisian gneiss occupies the middle position. It is, however, more probable that the gneiss occurs in the middle of a long-limbed isocline. The difference in the characters of the beds on either side now seems startling in view of the short distance between them, but we must remember that this distance may be much less than that which once separated the areas of formation of the beds. It has often been noticed, also, that as we follow some straight junction-line between the Moine rocks and the Lewisian gneiss, both these rocks vary considerably in character.

The Moine rocks show different stages of alteration in Mr. Clough. different districts. In many places they are represented by veined gneisses, in which half of the rock is composed of thin lenticles and streaks of pegmatite, while in the other half the minerals developed are unusually large. Veined gneisses, partly of a siliceous and partly of a micaceous type, are well seen in the following places: between Strath Chomair and Biod an Fhithich, at the Creagan Dubh of Ghleann Aoidhdailean, the top of Sgurr Mhic Bharraich, and on the watershed extending S. of this hill for two miles or so. Besides the thin pegmatites above referred to, which are repeatedly folded with the beds, there are, in certain areas in which the rock is not always veined with thin pegmatites, many thick, well-defined bands of pegmatite, as much as 50 yards broad, which cross both the Lewisian gneiss and the Moine rocks. These bands are later than the thin folded pegmatites, and they often cross quartz veins and beds which have previously been intensely folded. In one locality some of the bands have been sheared and partly granulitised.

After the Lewisian gneiss and the Moine rocks had been invaded by pegmatites and folded, they were pierced by a series of intrusive rocks, which we may call the Glenelg - Ratagan complex.* The largest outcrop of these rocks extends from near Suardalan rather more than three miles in a N.N.E. direction, and the average breadth is two miles. Wherever they are seen, the outer margins of the main mass and the minor outcrops are very jagged, and formed of rocks which are quite unchilled.

In the field the rocks can be roughly divided into three groups, each of which includes several varieties, that seem to pass into one another, and in certain places the rocks of one group also pass gradually into those of another. The groups are as follows:—

- A. Biotite granite (or granitite), biotite hornblende granite, pale syenite.
- B. Dark syenite, augite syenite, mica augite diorite.
- C. Pyroxenite, biotite pyroxenite, hornblendite.

The rocks of the ultrabasic group C. contain a small proportion of orthoclase. The syenite in group A. contains a very small proportion of the ferromagnesian constituents, and a little quartz.

On the W. side of the complex there is a granite, which passes gradually eastwards through Tonalite into Diorite, but farther E. the rocks of group A., including a granite of somewhat different character from that at the W. side, often intrude into, and include portions of rocks in group B. In one place rocks of group B. clearly intrude into others of group C., and we infer that they often do so from the numerous inclusions of pyroxenite, &c., they contain.

The dark syenites and diorites often show flow structures, and sometimes have such a prominent banding that they might be

* The E. portion of this complex has not yet been surveyed.

Mr. Clough. taken for Lewisian gneisses. Short strings of granite or granite porphyry, irregular in direction and without chilled margins, frequently cross the banding.

The rocks of groups A. and B. are in some places sheared in thin nearly vertical bands, which have been thoroughly granulitised. These are never more than a few feet thick, but in some places, *e.g.*, on the coast half a mile N.W. of Ratagan, they are so crowded that they form a considerable proportion of the rock.

In and near the complex there are some dark basic dykes, which are foliated and cut by strings of granite porphyry. One of these dykes is called by Dr. Flett a mica diorite. A considerable number of unfoliated dykes, including quartz felsites, porphyrites and mica traps, pass through rocks of the complex, and have thoroughly chilled margins. Their general direction is W.N.W.

(2).—*Inverguserran*.—In this district nearly all the rocks belong to the Moine series, but near Rudh' Ard Slisneach there are also small patches which may be grouped with the Lewisian gneiss.

In no place have the Moine rocks been converted into veined gneisses, but many of them, especially the more micaceous, are crowded with small spots, usually from $\frac{1}{8}$ to $\frac{1}{16}$ inch in diameter, of secondary felspar, apparently albite. A broad zone of garnetiferous mica-schist, which is well exposed on the coast near and S. of the village of Airor, contains a good many impure calcareous lenticles and thin calcareous beds, rarely more than a few inches thick, which still show elastic grains more than half an inch long, chiefly of quartz. The zone has a considerable resemblance to the Loch na Dal series,* but is in a much more altered condition.

The igneous rocks are all dykes, and later than the period of foliation and folding of the schists. They may be divided into three groups—

1. Diorite.
2. Mica traps and lamprophyres.
3. Rocks of Tertiary age. (These are described elsewhere, *see* p. 114.)

The two first groups are of small extent and their relations are doubtful. The general direction of the dykes of group 2 is nearly E. and W.

Physical and Economic Features of the Glenelg District.—The area surveyed near Loch Duich and in Glenelg is for the most part of a wild hilly character, but the igneous complex already described forms an exceptionally green smooth tract, and a considerable part of it is said to have been under the plough about 80 or 90 years ago. Most of the rocks of the igneous complex disintegrate readily, and give rise to soils which are presumed to be rich in alkalis, and perhaps also in apatite—a mineral which is a noticeable macroscopic constituent of the rocks.

* The lowest series but one of the Torridonian rocks of Skye,

Near the head of the Glenbeg of Glenelg there is a vein of Mr. Clough. galena, about four inches broad, but it is only seen in the stream-bed.

The largest peat moss, occupying perhaps a quarter of a square mile, lies about three-quarters of a mile W. of Suardalan, but being some distance off any house, it is not cut for fuel. Most of the shepherds have peat near their own homes, which is generally of excellent quality, though sometimes in small patches. In a peat moss rather more than half a mile N.W. of Bealachachasain there is a sulphur well, which once had considerable fame, but it is not so strong as formerly.

All the hill ground is pastoral, but on the side of Loch Duich, and near some of the houses, there are a few ploughed fields. The population is very sparse, and the ruins of several crofter hamlets are noticeable in the Glenmore of Glenelg. Near Inverguseran the 100-feet raised beach was formerly under cultivation, both along the shore and in the glen, and a small part of the same beach is still cultivated near Aior. The gravel in the present and the 20-feet raised beach near Inverguseran is very clean, and the pebbles in it are for the most part hard and siliceous. It is occasionally shipped for use in gardens in more populous districts.

With the exception of five isolated houses, most of them occupied by shepherds or keepers, the population is confined to the picturesque hamlet of Aior. There is a good natural harbour here, and the people make their living partly by fishing.

Fannich Forest.—In the autumn Mr. Horne completed the small patches of unsurveyed ground at the head of Loch Fannich, Ross-shire.

Part of this area lies to the north of Loch Fannich and along the south side of the Fannich watershed, extending from A'Chailleach (3,276 feet) by Sgurr Breac to Sgurr nan Clach Geala (3,581 feet). The various groups of crystalline schists identified and traced by Mr. Gunn on the N. side of the Fannich mountains (*Summary of Progress*, 1897, p. 38; 1899, p. 10) have been followed southwards to Loch Fannich and the hills beyond. A description of the geological structure of the south portion of the Fannich group, so far as the lines had then been traced by Mr. Horne, appeared in the *Annual Summary*, 1898, p. 11, and 1899, p. 8. In the latter Report (pp. 8 and 9) reference is made to the occurrence of a belt of acid gneiss with basic bands and lenticles of epidiorite and hornblende schist, resembling certain types of Lewisian gneiss, which belt, in the western part of the Fannich group is both underlain and overlain by garnetiferous muscovite-biotite schist. During last autumn the boundaries of this belt were traced from the watershed between Sgurr Breac and Sgurr nan Clach Geala southwards by Torran Ruadh to near the north shore of Loch Fannich, and westwards by the mouth of Allt nah-Ara, $1\frac{1}{4}$ miles east of Cabuie, towards the Nest River (Abhuinn Nid). Along the line of junction with the underlying and overlying muscovite-biotite schist, where there probably was considerable differential move-

Dr. Horne. ment, the acid gneiss shows marked linear foliation, with "eyes" of felspar, and resembles the granulitic schists of the Moine type. In places, however, it is coarsely granulitic, highly quartzose, with muscovite and biotite. The distinctive feature of the belt is the presence of basic bands, sometimes massive with hornblende and plagioclase felspar, and sometimes foliated, which transgress the foliation planes of the acid gneiss. One of these has been traced for a third of a mile on the south slope of Creag nah-Ara east of the head of Loch Fannich, and another for half a mile southwards, from the head of Allt Leac a' Bhealaich.

The muscovite-biotite gneiss with thin pegmatites and lenticles of garnetiferous hornblende rock that overlies the belt of acid gneiss just described, forms the crest and south slopes of A'Chailleach and of Sgurr Breac; it is exposed in Allt Leac a' Bhealaich and is continued southwards in Sail Mhor to Creag nah-Ara near the head of Loch Fannich. An examination of the crags on the south slope of Sgurr Breac and also on Sail Mhor reveals the puckering and overfolding of the muscovite-biotite gneiss.

Another patch of ground completed in the autumn lies about three miles to the west of the head of Loch Fannich and to the north of the Cabuie River, where the rocks consist of granulitic quartzose schists of the Moine type with a zone of biotite schists. The latter has been traced from the watershed at the head of Allt a' Chleibh southwards to the Cabuie River, and is probably the western prolongation of the Sgurr Mòr Fannich band.

Mr. Gunn. The small area completed by Mr. Gunn in the Fannich Forest lies mainly on the south and east sides of Beinn Liath Mhòr Fannaich, and the ground is nearly all above the 2,000 feet contour. The schists of this area are of the usual quartzose Moine type, with occasional thin bands of biotite schist. These rocks are bounded on the west by the thick mass of biotite schist which forms Sgurr Mòr. The rocks are intensely folded, the axis of the folds trending between north-west and north, and the dip of the folds being to the west. This is the structure of the southern inclination of the part of the area adjoining Abhuinn a' Ghiubhais Li', but as we follow the rocks northward the folds become vertical, or nearly so, and strike due north, the strike gradually trending to the east of north, and the steep-sided folds dipping easterly.

Mr. Hinxman *Ross-shire*.—The ground between Loch Garve and Strathconon (Sheet 83), on which Mr. Hinxman was engaged during the month of April, is for the most part bare and rocky, and the geological structure extremely complicated. The siliceous Moine schists and the coarse muscovite biotite gneiss by which the ground is chiefly occupied are interfolded in a most intricate manner; while between Tarvie and Strathconon there is, in addition, a great development of garnet-amphibolite, an intrusive rock which shares in the folding of the schists.

The basic rock occurs in more or less continuous sills and lenticular masses. These are thoroughly foliated with the schists, but are usually coarser and more felspathic in their central portions. Near the edge of one of these intrusions at

Comrie, where the mass is upwards of 300 yards in breadth, a thin band of ferriferous calc-biotite schist occurs, apparently along a line of crush. The edge of this sill shows a somewhat unusual modification of the igneous rock, probably due to the absorption of material from the contiguous schists. It contains, according to Dr. Flett, a little quartz and orthoclase in addition to the usual biotite and plagioclase, besides large masses of ferriferous carbonates, and plates of iron oxide. Crush lines are also frequent in the Moine schists, and are sometimes accompanied by bands of breccia two or three feet in breadth, made up of angular fragments of the adjacent rock.

Inverness-shire.—The area between Glen Strathfarrar and Glen Cannich, surveyed during the summer and late autumn months, is entirely occupied by schists and flagstones of "Moine" type, and garnetiferous muscovite biotite gneiss; both similar in lithological character to the rocks farther to the north and east that have been fully described in former reports.

Though there is evidence of a considerable amount of folding—especially in the lower part of Glen Cannich, and near Deanie Lodge in Glen Strathfarrar—it is on the whole of a less complex character than that found in Strathconon.

The muscovite biotite gneiss is largely developed in the western part of the area, and forms broad and well defined belts that can be traced continuously for some distance, and give rise to the more rugged features of the mountains in the Broulin and Glen Cannich forests. The general strike of the schists in this region is—neglecting minor flexures—between N.N.E. and N.E., while the limbs of the isoclinal folds usually dip to the east.

On the north side of Glen Cannich, in the south-west corner of Sheet 83, the rocks form a part of a broad anticlinal fold, on either side of which the dip is to S.W. and S.E. respectively.

The siliceous schists and flagstones of the Moine series largely predominate in the district east of Strathglass, between Glen Urquhart and the Beaully River, and the original argillaceous sediments are only represented by thin bands of biotite-muscovite schist, characterised by large "spangles" of white mica. Some of the highly siliceous schists are crowded with small pale-coloured garnets.

The zone of amphibolite sills which crosses the river Farrar at Struy, has been followed southwards along the western side of Strathglass as far as the foot of Glen Cannich. They present the usual character of these intrusions. Two of these sills are cut, a short distance west of Glassburn, by a vein of coarse muscovite pegmatite. At the point of intersection both this vein and the basic sills, as well as the surrounding siliceous schist, are highly garnetiferous.

With the exception of a few thin dykes of lamprophyre and mica-trap there appear to be no igneous intrusions in the rocks to the west of this zone; though the usual knots and veins of pegmatite and quartzo-felspathic material, probably of segregative origin, are abundant, particularly in the coarser gneisses. One of these pegmatite veins on the shore of Loch Mullie, contains crystals

Mr. Hinxman of tourmaline. The later dykes, referred to above, have a persistent east and west trend, and though never more than a few feet in breadth, can be traced for considerable distances, in two instances for more than three miles. In a specimen taken from one of these dark Minette dykes above the farm of Mid Crochail, Strathglass, Dr. Flett has detected the presence of a sky-blue secondary amphibole deposited on the surfaces or in the cracks of brownish-green hornblende, and in optical continuity with the primary mineral. The occurrence of secondary blue amphibole in crystals of hornblende has previously been noted by Flett in a lamprophyre from the Orkney Islands, and by Seymour in a hornblende-kersantite from Co. Down, Ireland.*

A parallel system of north-east and south-west faults, one of which has probably defined the straight course of Strathglass, traverses the ground on the east side of that valley. The relations of one of the mica-trap dykes to these faults show that the latter are of different ages. The position of the dyke is shifted by two of these faults, but in a third case it has been intruded along the line of weakness produced by the dislocation, and bending sharply from its former easterly course, follows the north-east trend of the fault for a distance of half a mile. This portion of the dyke contains numerous included fragments of the fractured schists, none of which appear in it outside the fault.

Ross-shire.—The area mapped by Mr. Hinxman during the month of June in the Inverlael forest, is occupied by siliceous schists and flagstones of the regular "Moine schist" type, with occasional bands of dark biotite schist, often garnetiferous. The latter vary from a few inches to (rarely) thirty or forty yards in breadth, and in some cases give rise to well-marked cliff features on the mountain sides. These rocks are evidently the altered representatives of a homogeneous mass of arenaceous sediments, probably of the nature of an arkose, with a few thin bands or seams of argillaceous material.

A line drawn nearly due north through Meall nan Ceapraichean and Eididh nan Clach Geala, indicates the position of an axis of plication along which the beds are suddenly rucked up into sharp asymmetrical folds, one limb of the fold being nearly horizontal, while the other may be vertical or even slightly overfolded.

Another zone of extreme plication crosses the summit of Meall Dubh, three miles N.N.E. of Inverlael. The overfolding is here far more pronounced, and the limbs of the folds often appear to be lying horizontally and parallel to one another. The structure of the ground between these two lines is generally simple. The beds dip at uniformly gentle angles, in directions varying from east by north round to south by west. This appearance of regularity is however possibly deceptive, for even where the beds seem to be arranged in regular succession, the crests of flattened overfolds can sometimes be detected,

* H. J. Seymour. "Occurrence of a Blue Amphibole in Hornblende Kersantite." *Geol. Mag.*, Dec. 4, vol. vii., p. 257.

and it is thus possible that only a small thickness of rock may be involved in the plications that cover a wide area. Mr. Hinxman

No igneous intrusions have been found in these rocks, but they contain frequent thin veins of quartz, and a few veins of pegmatite, both probably of segregative origin.

In the Allt na Lairige near its junction with the Douchary river, and also in the latter stream north of Creag Dubh, there are veins of quartz with which is associated a little plagioclase, felspar and a green pleochroic pyroxene which resembles agirine augite. The pyroxene occurs in strings or amorphous masses in the quartz and also in isolated idiomorphic crystals.

Physical and Economic features.—The greater part of the area surveyed by Mr. Hinxman during the past season is wild mountainous ground, almost entirely given up to grouse and deer. The cultivated areas are confined to the alluvial stretches along the larger streams, and the grouse moors support a certain number of sheep during the summer, but the amount of good grazing ground is very limited.

Owing to the hard siliceous nature of most of the rocks and to subsequent glacial action, there is over the area occupied by the Highland schists little or no surface soil due to disintegration. The corries and higher parts of the glens are, however, often filled to a considerable depth with stony morainic drift, which is not as a rule favourable to vegetation.

The thin dykes of Minette which traverse the schists in Strathglass decompose readily into an orange-red soil, which, from the abundance of apatite in the rock, is peculiarly fertile, and gives rise to stripes of vivid green herbage that stand out in striking contrast to the surrounding barren schists. The lower ground in Kiltarlity and at the head of Glen Urquhart is more fertile, and much of it is under cultivation. The soil is here derived from drift deposits, usually loose and gravelly above, but passing downwards into stiff boulder clay.

Beyond a few small openings, for local purposes, in the flagstones of the Moine schists there are no quarries in the district surveyed.

Large areas on the hill slopes and in the higher valleys are occupied by peat mosses, often of considerable depth. The peat is dug to a small extent for fuel where it is fairly accessible, and may be of considerable economic importance in the future.

The population is sparse, very scattered, and confined to the valleys. Water supply is abundant, of excellent quality, and far in excess of the requirements. The potential water power represented by the numerous natural reservoirs, streams, and falls in the district, is very great, but has not, so far, been made use of.

The sides of the larger valleys are well clothed with natural woods of pine and birch, with oak on the lower slopes. In Glen Strathfarrar the pine grows well, up to an elevation of over 1,100 feet above sea level. Large areas in Kiltarlity have been planted with coniferous trees, and there are also smaller fir plantations at the foot of Glen Orrin and in the higher parts of Strathconon. The natural wood flourishes well on rocky slopes

Mr. Hinxman where the soil is scanty, and there is no doubt that large areas of the ground under 1,000 feet in elevation, that are now barren moorland, but are shown by the remains in the peat mosses to have been once thickly clothed with forest, might be profitably replanted.

Mr. Gunn. *Ross-shire*.—The work done by Mr. Gunn in the Loch Broom area offers few points of interest apart from that of previous years, in the same district. For the most part the rocks belong to the siliceous Moine type of crystalline schists, the foliation of which dips at comparatively low angles of 10° – 20° to points between south and south-east. The rock is generally flaggy and the dip is fairly regular over large areas. Folds or plications can seldom be detected, though good outcrops in sears and in burn sections are numerous.

On the south side of the Lael Valley, at its head, sharp folds trending somewhat east of north are extremely numerous, but as we pass westward down the valley, they disappear in the course of a mile or so, and we find a series of quartzose schists dipping regularly to the southwest at about 20° . The dip gradually changes so as to become due south about Glensguaib, and then east of south, which is the general direction along the valley of Loch Broom.

The structure of the ground for a long distance north of the Lael is similar to that south of this river, but as we approach Meall Dubh, where there are bands of biotite schist, we again find the rocks much plicated. To the northward of this hill, the beds again appear regular and the strike curves round, as along the Lael, being north-east at Leckmeln and south-east near Douchary.

The line of Coire Granda to the east of Beinn Deirg, nearly coincides with the axis of a large anticlinal fold which dies out to the northward in a series of rapid plications. To the east of this corrie for a long distance, the siliceous Moine-schist with occasional thin bands of biotite schist dip steadily in a north-easterly direction, which gradually changes to an easterly dip along the east side of Allt Lair, and the beds are comparatively free from visible folds.

Dr. Crampton The ground on which Dr. Crampton was engaged during the month of June, is that part of the Inverlael Forest lying around the head of the Douchary River. It is difficult to reach, and the greater part of it is more than 2,000 feet above the sea. There is no population or cultivation of any kind on this ground, the whole area being very rugged and rocky, and under deer.

The crystalline schists are principally quartzose schists with varying proportions of micas. They are sometimes of a flaggy character, but mostly heavy gneisses, breaking up into large blocks. Alternating with the quartzose bands, are thin bands of a wavy bluish biotite schist, often containing garnet. They are largely developed on Meall a' Coire Glais and Tomain Coinich. Bands of garnetiferous mica schist, with larger proportions of muscovite, occur about the head of Chadha Dheirg, and on the eastern slope of the hollow leading thence to the head of

the Glen Beag stream. Over the N.E. flank of Seana Bhrugh the rocks dip S.S.E. at angles of 15° – 25° , and there is little folding to be seen. The rocks also dip at low angles, but due E. on Meall a' Coire Glais, while further to the south, round the Lochan Sgeirich, the dip is E.N.E. at angles of 20° – 30° . Throughout these districts small escarpments and dip slopes are common features and the dips are constant over wide areas, but further east about the head of Chadha Deirg, and between this and Sron an Tomain Coinich, the folding begins to be marked, and contorted folding is beautifully shown in Creagan Tomain Coinich and the cliffs at the eastern end of Chadha Dheirg.

Strathvaich.—The part of the Strathvaich Forest, surveyed by Dr. Crampton from his station at Aultguish Inn lies between the Glascarnoch River and the Strathvaich River, and stretches northward along the west side of Strathvaich as far as Loch Toll à Mhuic.

The crystalline schists form nearly the whole of this area. They are chiefly granulitic quartzose rocks of the Moine type, with subsidiary bands of muscovite-biotite schist.

Along the western slopes of Strathvaich the strike of the rocks is almost due N. and S., but north of Aultguish Inn it becomes S. 10° E.—N. 10° W., and this is continued over Meall an Torcain, Tom Ban Mòr, and the heights further to the north. The folding of these schists is nearly vertical in the eastern part of the district, the dip being sometimes westerly sometimes easterly, but always at high angles. On passing westward the folds gradually dip at lower and lower angles to the eastward, till, near Airicheirie, the dip is E. 10° N. at 30° . In the intermediate areas, on the heights of Meall an Torcain and Tom Ban Mòr, the dips are 60° – 45° gradually acquiring a lower angle towards the westward. Thin bands of brown biotite schist from a few inches to several feet in thickness are common all through the series, but they acquire a greater development on the line of strike, passing from Meall an Torcain over Meall Coire nan Laogh towards Carn Gorm Loch. Here a series of thicker bands some yards in width, but with intercalated bands of quartzose schists, occur, over a breadth of 300 yards. They consist of wavy bluish-black biotite schist, weathering a brownish colour. Small garnets are not uncommon. To the west of these biotite-schists bands, on the south-west slope of Meall an Torcain occur two well-marked bands containing many garnets. They cross Tom Ban Mòr, and Meall Ghorm, to Meallan Ban, where they pass out of the district surveyed. The rock is a flaggy muscovite biotite schist, full of small perfect garnets, very similar to the muscovite biotite schists of Eastern Ross, but the structure is less coarse. Accompanying these bands are white pegmatites with large crystals of muscovite, and occasional garnet. A large pegmatite of this description with a breadth of 15 yards can be followed from near Craig Rainich, across Tom Ban Mòr, on to Tom Ban Beag, apparently following the strike of the schists.

Dr. Crampton About half a mile to the east of Aultguish Inn, a series of small crushes occurs in the schists exposed in the banks of the Glascarnoch River.

Mr. Gunn. Crystalline schists of the Moine type occupy most of the area on the east side of Strathvaich, to the north of Strathvaich Lodge. They have a prevailing northerly strike, generally trending a little to the west of north. The beds are usually vertical, or dip at steep angles to the westward, but sometimes the dip is easterly. Not much folding is visible in this area, nor are there any marked bands of biotite schist.

A pink-augen gneiss or foliated granite, which is intrusive in the crystalline schists, occupies all the area between Black Water and the Strathrannoch Burn, for a distance of $2\frac{1}{2}$ -miles northward from Inchbae Lodge. Much of this area is covered with drift and peat, and the rock is not well exposed, except to the north of the school-house at the Black Bridge, where it forms a fine series of escarpments trending a little west of north. The foliation in this place dips eastward at a high angle, but about Luibfearn in the direction of Inchbae, the dip is considerably to the south of east, and the amount is not generally more than 30° or 40° .

The character of this rock is the same as that described in the reports for previous years,* and therefore does not require a detailed notice. The rock extends for some distance to the east of Strathrannoch, and has again been encountered by Mr. Gunn in the Kincardine districts of Ross-shire, and by Dr. Crampton in Strath Rusdale and the neighbourhood—*See infra*.

Dr. Crampton *Strathrusdale*.—In the Alness district of Ross-shire, Dr. Crampton who was stationed in Strathrusdale, found the greater part of his area composed of various kinds of crystalline schists with associated igneous rocks. The latter consist of the augen-gneiss and hornblendite sills. The north-eastern corner of the area is occupied by an intrusion of unfoliated granite. Two very small exposures of scyelite occur near the summit of Meall nam Gabhar.

The crystalline schists occupy the greater part of the area. The prevailing type of rock is a granulitic quartzose schist. A broad band of dark muscovite biotite gneiss is the only one which has been definitely traced across the whole area. This rock contains large flakes of white and black micas and strings of felspathic and pegmatitic material. It is frequently full of garnets, which are sometimes small with good crystalline faces, but often form aggregates from the size of a pea to that of a walnut and with a crushed appearance. This band is in places more than half a mile in width without any other kind of rock. It enters the area at the northern end of Ben Tharsuinn and crossing Strathrusdale in a S.S.W. direction extends as far as the Alness River in the Boath Valley where it is cut off by a fault. The band reappears on the S.W. shore of Loch Morie, about one mile from the outlet, and forms a crag facing the loch.

* *Summary of Progress* for 1898, p. 9, and for 1900, p. 8.

It then passes over Meall Beag in a S.W. direction. The dips of this rock in the most northerly part of the band are very high and mostly in an easterly direction, but with occasional reversals to the W. As the band passes southward into Strathrusdale the dips have an E.S.E. direction at angles of 50° – 60° . Further south and on the south side of the fault the dips become S.E. at angles usually about 45° . To the south and east of this band, and apparently overlying it, is a series of thin bands of a yellowish quartzite, weathering on the surface to a pure white, and alternating with bands of muscovite biotite gneiss of much the same character as the broad band described above. With these occur a thick series of flaggy granulitic quartzo-felspathic gneisses and bands of a more massive character, with a large proportion of pink felspar in strings and lenticles. Where the alternations of muscovite biotite gneiss and quartzo-felspathic rocks are more rapid there is a tendency for both members to become very flaggy in character, and to pass gradually from one kind of rock to the other through intermediate rocks called "spangle schists." These are granulitic quartzo-felspathic rocks of a very flaggy character and they contain scattered through them large flakes of muscovite which give the cleaved faces of the flags a spangled appearance. With these rocks are associated strings and lenticles of white pegmatite containing large crystals of white mica, which frequently enclose garnets. These pegmatites are sometimes of a large size and appear like dykes. The strike and direction of dip of all these schists which lie to the S.E. of the large band of muscovite-biotite-gneiss coincide in the main with the strike and dip of that band as described above. The broad belt of muscovite-biotite-gneiss on its N.W. margin is succeeded rather abruptly by granulitic quartzo-felspathic schists of the Moine type which appear to dip beneath it. Schists of this type devoid of bands of muscovite-biotite-gneiss, but enclosing some of biotite schists, occur all over the wide region to the west as far as Bad a Bhathaich and the northern end of Loch Morie. The strike and dip of these rocks follow the general direction of that of the schists to the eastward, but throughout the regions of Carn Beag and Craig Braigh and Stratha and to the west of these elevations, the rocks are much contorted and folded, the dips being frequently to the S., S.W., and West. A thick band of bluish grey mica schist with a finely crimped structure caps Carn Beag and extends about one mile southward towards the outlet of Loch Morie. It is much interfolded at its margins with the underlying quartzose schists. Its general dip seems to be to the S.W., but there is much contortion. Along a line beginning at the junction of Allt Coire na Capuill with the Amhainn Glac and passing in a S.S.W. direction west of Bad a Bhathaich and thence through Meall Toll a Choin, above Kildermorie, the quartzo-felspathic schists give place to bluish-grey mica schists of the same type as those capping Carn Beag, but not so crimped and generally of a more phyllitic character. These mica schists dipping sometimes to S.E. and sometimes to

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Dr. Crampton S. and S.W. pass gradually in a westerly direction into a bluish-grey hornfels. Rock of this type forms a zone of metamorphosed sediment, with a width of about half a mile, bounding the augen-gneiss described below. The minerals of the hornfels are usually too small to be distinguished with the naked eye. The rock as a whole has a very homogeneous appearance but distinct banding on a very small scale, evidently that of original bedding, is brought out on weathered surfaces. Near the margin of the augen-gneiss minute knots occur, and within a few yards of the junction large garnets have been developed and the rock is extremely hard and has a very baked appearance.

Dr. Flett has examined sections of the hornfels which has been produced by the augen-gneiss evidently acting as an igneous intrusion. He states that they are "finely banded hornfelses in which knots are well developed so that they may be described as Knotenschiefer. The banding is probably original bedding. Under the microscope they are fine-grained and consist of biotite, muscovite, quartz, and felspar. Small garnets spongy with enclosures are frequent. The knots consist of subradiate scales of pale mica. In one or two slides the original grains of clastic quartz are still to be traced in certain more gritty bands. Some of these hornfelses show no trace whatever of mechanical deformation subsequent to the thermal metamorphism." One of the specimens from Crag west of Kildermorie Lodge is a garnetiferous sillimanite biotite hornfels. Sillimanite in tufted needles is very abundant from the river bed west of Kildermorie Lodge. Another specimen shows garnets over $\frac{1}{4}$ in. in diameter filled with enclosures of quartz, magnetite, etc. Clinocllore, green hornblende, and rutile are present. It is, therefore, evident that these rocks retained many of their clastic characters at the time of the introduction of the augen-gneiss, which in the respect of the hornfelsing has behaved as an igneous mass. In virtue of this hornfelsing they have escaped being converted into schists of the Moine type into which they pass out laterally.

The best exposures of the rocks of this metamorphosed zone are seen in the crags on both sides of the river above Kildermorie Lodge. There is also a good section in the river bed where the hornfels can be traced right up to its junction with the augen-gneiss. The junction is also exposed on the north bank of the river and at the summit of Carn Cas nan Gabhar.

Augen-gneiss, like that of Inchbae, is seen in junction with the hornfels in the river about half a mile above Kildermorie Lodge. The rock is a foliated granite in which a matrix of quartz, felspar, and black mica flows round large eyes of felspar. The line of junction passes in a N.N.E. direction up the Crag on the north bank of the stream, and the augen-gneiss has been followed to Carn Cas nan Gabhar, where it is seen near the summit of the mountain in junction with the schists. On the south bank of the river above Kildermorie Lodge the line of junction swerves to the N.W. and again crossing the river passes up the burn coming from Lochan Lice. The line

of junction again changes its direction and is continued W.S.W. Dr. Crampton so as to cross the river once more about a quarter of a mile below the bridge. The strike of the foliation where observed is N.N.E. and S.S.W. The margin is rather abrupt in the region about Kildermorie, but small tongues and veins of the rock penetrate the schists. At the summit of Carn Cas nan Gabhar the junction can only be described as an intricate network of schist and igneous rock. Inclusions of schist are frequent within the margin of the gneiss, which sends out veins sometimes foliated like the gneiss itself but often quite devoid of any foliation, into the schists all along the boundary. The smaller veins are crowded with small rounded grains of blue quartz.

Hornblendites.—Small lenticular sills of hornblendite containing garnet occur associated with the muscovite biotite schists and also with the quartzose rocks. The largest, about 30 feet across, are seen in the Craig Ard a Briarh. The margins of these lenticles are well foliated and often show ball-like masses of crushed garnet wrapped in scales of brown biotite.

Seyelite.—Two small exposures of seyclite occur in the peat 300 yards N.N.E., and 400 yards E.N.E. of the cairn of Carn Cas nan Gabhar. They appear to have a somewhat dyke-like extrusion, but their relations to the surrounding rocks are not seen. Patches of a rock of a more acid character full of hornblende crystals are seen sticking to the seyclite in the more northerly exposure.

Dr. Flett, who has examined specimens taken from the more northerly exposure, calls the rock a biotite-hornblende-peridotite or seyclite. The beautiful lustre mottling seen in the hand specimen is due to the hornblende enveloping the biotite in poikilitic fashion. There is no shearing structure, but cracks and distortion of the biotite and hornblende, due to expansion of the olivines during weathering, are very noticeable. The rock closely resembles the original seyclite of Professor Judd (*Q.J.G.S.* 1885, Vol. 41). The more acid rock sticking to the seyclite is a quartz diorite of a basic kind almost approaching a hornblendite. Green hornblende, showing good crystalline outlines and brown biotite, are associated with a peculiarly acid interstitial material consisting largely of micropegmatite.

Granite.—A pale pink granite, an extension of a larger mass to the northward, occurs on the north-east flanks of Beinn Tharsuinn and Doire Leathann. Its constituents are a pink felspar, large clear quartzes with a strong tendency to good crystalline outlines, and small flakes of a brownish biotite. The latter is almost absent in some places, especially in the numerous veins which penetrate the schists along the margins. The metamorphism produced by the granite on the schists is very slight, and apparent chiefly in the direction of a greater development of muscovite. Boulders of this granite occur in conglomerate of Old Red Sandstone age about one mile distant in the Strathrory River. These boulders had been previously noticed by the late Hugh Miller. Dr. Flett reports on an examination of a slice of

Dr. Crampton this granite, that it is a biotite granite containing microcline. Orthite is present as an accessory.

The population in this area is distributed along the Blackwater River in Strathrusdale, and the district of Boath. It consists of the inhabitants of about a dozen crofts, who gain a living almost entirely by sheep farming. The only cultivated lands are narrow strips on the alluvia of the Blackwater and Alness rivers, and larger patches in the neighbourhood of Boath on the mudstones of the Old Red Sandstone. The crops grown are oats, turnips, and potatoes for home consumption. Kildermorie Lodge also lies in the area surveyed, and is surrounded by a few keepers' houses.

The boulders of augen-gneiss have been used largely throughout the district for the building of houses and bridges. One boulder supplied material for two cottages, with rock to spare. It is said that the rock splits well and makes an excellent building-stone. The method used for splitting the stone is called "pegging and feathering." Over the greater part of the district the land is not fit for cultivation.

Mr. Gunn.

Kincardine district.—The principal rocks which are found in the Kincardine district are crystalline schists, augen-gneiss, and granite.

The crystalline schists of the Kincardine district are mainly of the siliceous Moine type. They are, in general, flaggy, with a fair amount of mica, especially on the bedding planes, but in not a few places they are thick bedded and very quartzose, and the mica is sparsely developed; while in some places the rock is massive, and the foliation obscure. The dip of the foliation is generally southward, and at high angles along the Carron River. The same dip is continued a good way up Allt Downie, but is less in amount, and the beds are repeated by a series of flattened folds. Over the large part of the Kincardine area the foliation dip is generally directed between E.S.E. and S.S.E., so that the average strike of the rocks may be said to be north-east. Near the northern edge of the main mass of granite, however, the strike tends to become parallel to the boundary line of the granite, or W.N.W. A marked example of this kind may be examined up Wester Fearn Burn. About Conà Chreagan Clach there is a considerable area where the rocks are sharply plicated in a north and south direction.

Two broad bands of muscovite biotite-gneiss have been traced in the neighbourhood of Easter Fearn, and under Struie Hill. They are separated by a band of siliceous schist, which is half a mile wide opposite Struie, but which apparently becomes very narrow near Corriefearn, so that it seems probable one band is a folded repetition of the other. One of these forms Dun Crieich, on the north side of the Dornoch Firth. There is no doubt that these bands are a continuation of one which has been traced by Dr. Crampton, in a north-easterly direction from Strathglass, across Strath Rusdale, till it is truncated by the granite north of Beinn Tharsuinn.

Thin bands of hornblende-schist occur on the shore, and in the railway cutting two miles east of Easter Fearn, and some small masses of epidiorite and of hornblende rock are found in a few places. Mr. Gunn.

Augen-Gneiss or Foliated Granite.—The north-eastern extremity of the augen-gneiss or Inchbae rock, curves round from Carn Salach, and Carn Bhren, by Carn an Liath-bhaid to Meall na Cuachaige, but only a part of the boundary has been mapped. It is evidently of the nature of an intrusive granite sill which has been folded and foliated with the schists. In this district it appears to be everywhere in contact with rock which was once an argillaceous sediment, and which has undergone a great amount of alteration, having been converted in great measure into a hornfels with a development of contact minerals as andalusite, &c.

The width of this mass of igneous rock where it is known at either end (Inchbae or Carn Bhren), is from two to three miles, and it is probable that there is a continuous outcrop of it forming an isoclinal fold, stretching for about seventeen miles from its S.W. extremity near Beinn nan Cabag to Carn an Liath-bhaid at its N.E. boundary. This direction appears roughly to coincide with the general strike of the schists, into which it was intruded, and is in striking contrast with that of the greatest length of the mass of unfoliated granite which is found to the east of it, on the south side of the Dornoch Firth near Kincardine. The latter trends to the N.N.W., and cuts markedly across a thick band of muscovite biotite gneiss which strikes N.E.

Granite.—The mass of pink or red unfoliated granite stretches in a N.N.W. direction for a distance of six miles, from the Strathory River beyond the Wester Fearn Burn, but the central portion of this area is not yet completed. Its average width is more than two miles. To the north of the main granite area small bosses and veins of granite occur in several places. They are particularly numerous along the shore south of Ardgay, and in Church Hill. This reddish biotite granite is in general moderately coarse, and the quartz which it contains often tends to become idiomorphic. The biotite is sometimes but sparingly developed. In places *e.g.* in the main part of Easter Fearn Burn, the granite is much decomposed, and very soft. There is a fine section of the rock in the gorge of the Wester Fearn Burn, where the granite is harder, and where it includes two broad bands of siliceous-schist.

As fragments of this granite are found in the lower Old Red conglomerate, it is clear that its intrusion was prior to the Old Red Sandstone period.

Two dykes of mica-trap running in an east-south-east direction pierce the schists in Allt na-h-Eiteig, and in Wester Fearn Burn dykes of a somewhat similar character penetrate the granite.

OLD RED SANDSTONE.

Ross-shire, Achilty.—The mass of coarse basal breccia that Mr. Hinxman forms the summit and eastern face of Torr Achilty lies between

Mr. Hinxman two faults, both with a down-throw to the east. These faults have been traced through the schists on the south side of the Conon, and after crossing that river they run in a N.N.E. direction, until they probably converge beneath the alluvial plain which lies between the base of Torr Achilty and the village of Contin. The most easterly of these faults throws down a pebbly conglomerate with intercalated beds of grey shale against the basal breccia on the west, which contains angular blocks of schist three and four feet in length. The breccia and the intercalated series on either side dip in opposite directions towards the fault. By the other fault the breccia is brought against the Highland schists half a mile further to the west. The down-throw of this fault on the southern face of the hill is evidently small, but on the north side the breccia lies in a deep hollow against a steep cliff of schist. Between the two faults the Old Red Sandstone rests unconformably upon nearly vertical beds of reddened and shattered siliceous schist.

Inverness-shire.—The western boundary of the Moray Firth Old Red Sandstone Basin has been traced southwards and eastwards from the Beaully river at Eskadale to the head of Glen Convinth. The base of the formation is everywhere a coarse conglomerate-breccia—a tumultuous aggregate of rounded and subangular fragments of all sizes, from small pebbles up to blocks three and four feet in length, set in a sandy matrix.

The included stones are almost entirely derived from the local crystalline schists, but there are also a few rounded boulders of unfoliated biotite granite and pegmatite, one of the latter measuring six feet in diameter.

A short distance in from the margin, beds of shaly greenish and red sandstone are intercalated with the conglomerate, but these do not exceed a few feet in thickness.

Mr. Gunn.

Strath Vaich Forest.—The Old Red Sandstone occupies a strip of ground more than a mile in width, on the east side of Strath Vaich, between the Moine schists and the augen gneiss, and it runs a long way up the main stream of Strath Rannoch. An outlier of this formation also caps Meall-a-Ghrianain (2531 feet). The Old Red strata rest unconformably on both the older crystalline rocks, and its basal breccia is largely made up either of fragments of augen gneiss or of schist, according to the character of the rock on which it reposes. It appears that the surface of the crystalline rocks immediately prior to the deposition of the Old Red Sandstone must have been very irregular, and somewhat comparable to that of the Lewisian gneiss when the Torridonian formation was formed.

The Old Red Sandstone consists of breccias and conglomerates, sandstones, and mudstones. No regular succession can be made out satisfactorily as the ground is much obscured by drift and peat, and there are probably faults which are not visible. In the burns east of Creag Bhreac Mhor there are sections in purplish red mudstones, in which occur green streaks and also sandy bands. These latter show that the rock dips to the south-east at

comparatively low angles of 15° to 20° , while the most prominent Mr. Gunn. planes, those of cleavage, dip to the N.N.W. at angles of 50° to 60° .

The outlier which forms Meall-a-Ghrianain is remarkable. As far as can be made out it consists almost entirely of blocks of augen-gneiss in a somewhat sandy matrix. The blocks are of large size, many being as much as ten feet in length, and there are some still larger. On the south-east side of the hill blocks of schist were also noticed in the conglomerate. There is no satisfactory outcrop on the hill top, which is covered with loose blocks of augen-gneiss apparently derived from disintegration of the breccia. The best section of the mass is on the west side of the hill about 550 yards W.N.W. of the ordnance station, and the cliffs there expose more than a hundred feet of the conglomerate. In one place there is an intercalated band of reddish sandstone one foot in thickness which has a gentle southerly dip, and this is probably the dip of the whole outlier, for the base of the mass must be 300 or 400 feet higher at the north than at the south end.

The large blocks of augen-gneiss so abundantly scattered over the area between Strathvaich and the Glascarnoch Valley were probably derived from this outlier, having been distributed during the glacial period.

It is difficult to account for the composition of this mass, as no augen-gneiss is known to occur *in situ* anywhere near it, and the blocks of which the basal portion is composed appear everywhere to repose on the ordinary siliceous Moine schists of the district. It is quite possible, however, that there is a core of augen gneiss *in situ* near the summit of the hill, concealed under the *débris* of the conglomerate.

The size of the blocks in this breccia is far above what usually occurs in the basal conglomerate of the Old Red Sandstone, in which the stones seldom exceed the length of two feet, and most of them are below that size. An exception to this, however, occurs in the basal breccia near its unconformable junction with the schist in the stream nearly a mile east of the summit of Meall-a-Ghrianain, where one of the blocks occurring in the breccia is 18 feet in length.

Reference was made to these areas of Old Red Sandstone in the Annual Report for the year 1896, p. 53, but they had not then been surveyed. It is known that rocks of this formation extend for a considerable distance to the east of Strath Rannoch but this part is not completed.

Three small outcrops of conglomerate which are found in the Dr. Crampton banks of the Strathvaich River between Lubriach and the Black Bridge were mapped by Dr. Crampton. Two of them are connected with the Old Red Conglomerate to the eastward, while the third which is the nearest to the Black Bridge is probably a smaller outlier. They consist entirely of schist pebbles in a red matrix.

Alness District.—A junction of the schists and Old Red Sandstone is to be seen in the Tollie burn one and a quarter mile above the bridge at Ardross gates. The Old Red Sandstone

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distinctly faulted against the schists shows here a thin conglomerate which can hardly be separated from the brecciated schist occurring in the fault. The conglomerate is succeeded by red sandstones and thin purple and green mudstones all dipping to the S.W. The mudstones can be followed in the burn as far as Bractollie. The direction of the fault is N. 35 E.—S. 35 W.

The other area in which the Old Red Sandstone enters into the ground surveyed is in the Boath district. Here the line of junction of the Old Red Sandstone and the schists is partly a fault and partly also an unconformable one. The N.E. face of Cnoc Liath Fad down to the 1,000 feet line consists of a conglomerate of schist fragments and pebbles in a reddish matrix. On the south slope of the hill the conglomerate is in unconformable junction with the schists which at the W. end of the hill are in place as high as the 1,750 feet line. The line of junction has an abrupt descent at the N.W. end of the hill and crosses the low lying ground immediately south of Craig na Glaic and Boathvie towards the junction of the rivers near Strone. The basal conglomerate of Cnoc Liath Fad gives way to a series of purple and bluish-black mudstones in the low-lying ground about Glack, but the relation of the two sets of rocks to each other is obscure. There is however a thin basal conglomerate south of the Craig na Glaic. The whole of the low-lying area of Boath consists of purplish mudstones with occasional thin sandstone, which are well seen in the burn sections, but elsewhere they are largely covered by drift. These mudstones are limited in their northward extension by a fault lying a little to the S. of the Alness river, which brings them in contact with the schists. A second fault seen in the burn above Ballone brings the series against the schist to the south. Cnoc Liath nah-Acain forms the northern extremity of a ridge of conglomerate extending from Meall an Tuire in Strathglass. The conglomerate is faulted against the schists to the W. by the great boundary fault the extension of which to the N.E. in the Boath district is obscured by drift. The dark bluish mudstones immediately to the W. of Glack show pale blue phosphatic marks which suggest fish remains, though nothing more definite has been observed.

TERTIARY.

Mr. Clough. *Inverguseran*.—Tertiary Dykes are somewhat numerous in the south part of the Inverguseran district. Most of them are basaltic and tend N.W. or N.N.W.

GLACIAL PHENOMENA.

Glenelg District.—Glacial striae cross the Glenelg-Loch Duich watershed in Bealach Ratagain in the pass a mile N.W. of Sgurr Mhic Bharraich and in other places, one of them more than 2,500 feet high, further S. Granite boulders occur on the N.E. side of Bealachachasain house, and must have been carried over the watershed in a S.W. direction. Granite boulders have also

been carried S.W. right across the main area of diorite and augite syenite on to the Lewisian gneiss rocks near Strathchomair. This probably indicates that the pressure of ice coming over the watershed from the N.E. and E. was at one time so great that the ice from the E. slopes of Ben Sgriol and Beinn a' Chapuill was unable to advance eastwards. Mr. Clough.

The floors and sides of the glens are to a large extent covered with small morainic mounds, but deposits of stiff grey boulder clay also occur. Excellent exposures of this clay are found near the heads of Ghleann Aoidhdailean and Bealach a' Chasain.

A little E. of Strathchomair, and on the low watershed between the Gleann Beag and Glen More of Glenelg, there is an extensive and thick deposit of fine sand and gravel. The materials composing the deposit are exposed in a good section, where they are quite free from large boulders, though such boulders occur in abundance scattered over the top and on the sides of the outcrop. The sand must have been deposited in still water, and probably in a loch, though it is difficult to see how a loch can have existed in this locality unless some of the banks were formed by ice.

A little N. of, and about 40 feet higher than, the sharp bend in the Gleann Beag burn are remains of an old gravel terrace, the top of which is nearly horizontal though the burn below has a rapid fall. The terrace is very near the deposit mentioned in the preceding paragraph and possibly of the same age.

On the E. side of the burn, about a mile S. of Bealachachasin house, is a series of seven or eight short terraces, the N. and S. parts of which end abruptly against moraine covered slopes of about the same elevation. Perhaps these terraces were formed while most of the glen bottom and the sides were still covered with ice.

Fannich Forest.—In the Fannich Forest, well-marked groups of moraines were found by Dr. Horne, in the valleys draining into the Cabuie river, and at the head of Allt a' Chleibh, and Mr. Gunn reports that beautifully-formed moraines, which often trend nearly east and west are abundant to the east of Loch Li. Some of these, which are several hundred yards in length, are extremely narrow, run in almost perfectly straight lines, and have steep edges on their northern sides. Dr. Horne and Mr. Gunn.

Inverness-shire and Ross-shire.—The glacial drift in the higher parts of Strathglass and its tributary Glens, may all be referred to the later valley glaciation. It is only in the low ground valleys of Kiltarlity and on the northern slopes of Glen Urquhart that any true boulder-clay has been observed, in some cases underlying later morainic deposits. Mr. Hixman.

The glacial striæ and the dispersion of carried blocks in this region point to a general easterly movement of the ice outwards from the high mountainous region in the west.

Evidences of the later phases of the valley glaciation are abundant among the mountains of the Inverlael Forest, whose glens and corries afford splendid examples of lateral and terminal moraines.

Mr. Gunn
and
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Ross-shire.—The finest set of moraines occurs on the north side of the River Lael, at An Cnapach (The Knolls) to the south of Lochan a' Cnapaich. The water of the loch disappears under the loose material of the more conspicuous moraines and comes out again to the south in several fine springs. A well-marked moraine 500 yards in length, which trends north-east, occurs on the watershed north of the head of the River Lael, at a height of 2750 ft. above the sea, and there is a pretty series of moraines to the N.E. of this in the valley west of Loch Tuath. There is very little glacial drift in Dr. Crampton's part of the Inverlael Forest, and what occurs is of a loose character and full of blocks and fragments of the rocks in the immediate neighbourhood.

Mr. Gunn.

As will have been gathered from the description of Strathvaich Forest, much of the area is covered with glacial drift, but there are few good sections of it. The older boulder clay, or till, apparently overspreads a large part of the augen-gneiss area, assuming in Druim Buidhe the form of a drumlin trending south-east. Good examples of linear moraines are found in the valley east of Meall a Ghrianain, but perhaps the finest, which is nearly half-a-mile in length, occurs on the east side of a small stream to the north of Druim Buidhe. Large blocks of augen-gneiss from the conglomerate of Meall a Ghrianain, several as much as twelve feet long, have been distributed to the eastward, southward, and westward of the hill and they must have been carried, at one time, south-westward across the valley of Strathvaich. This was probably when the ice had attained its maximum thickness, and the ice-shed was considerably to the east of the present main water-shed of the north of Scotland. It seems probable also that those found scattered on the Loch Broom side of the present water-shed (see *Report of Geol. Survey for 1896*, p. 18) may have also been derived from the same outlier.

Dr. Crampton

Strathvaich.—Dr. Crampton, in his area, finds that the drift is thickest in the lower part of Strathvaich, where it has been cut through by the river and terraced. It consists of a loose earthy accumulation of large and small boulders of schist and augen-gneiss. The western slopes of Strathvaich are covered with moraines full of similar boulders. A fine series of Kames occurs immediately south of Strathvaich Lodge. The most noticeable of these has a serpentine form, and is 600 yards in length. Augen-gneiss boulders are plentiful on the heights south of Tom Bàn Mòr. One on Sron Ghorm measures 18' × 8' × 5'. Ice striae with S.E.–N.W. direction occur on the summits of Meall an Torcain and Sron Ghorm. Striae near the base of Meall an Torcain have a direction E.S.E.–W.N.W. A few blocks of conglomerate are scattered over the summit of Meall Coire nan Laogh.

Strathrusdale.—Glacial deposits of great thickness occur in the valley to the east of Cnoc Liath nah-Acain leading from Boath to the junction of the rivers in Glen Glass. Sections of this deposit 30 feet in depth occur in the Allt na Seasgach, without rock being seen in the river bed. This drift has much the appearance of till, containing large, much-worn boulders of augen-gneiss and schist, and is full of smaller *débris* of schist and mudstone. It is quite

loose and unconsolidated and appears to pass gradually into the thinner drift of the valleys to the westward. The low lying ground to the east of Doire Leathann in the basin of the Strath-rory river shows the same unconsolidated earthy drift of great thickness. Here, however, the predominant constituent is *débris* of the pink unfoliated granite which forms the ground to the N. and W. Small fragments of the Cambrian Pipe-rock occur in the drift of this area. One of the most noticeable features of the country is the quantity of immense boulders of augen-gneiss which occur everywhere up to the highest altitudes. Boulders of 10 feet diameter occur on the top of Beinn Tharsuinn. The largest boulder measured lies in the plantation to the N. of Bracantra in Strathrusdale. It is 61 feet in girth and 15 feet high. The augen-gneiss, however, occurs in places only three miles distant from this boulder. Fine examples of *roches moutonnées* are seen at the base of Cnoc a' Mhadaidh and on the opposite hill, Am Mam, and the striae found upon them point E. 30 S., and their long axes are arranged in the same direction. A few boulders of Scyelite occur near the large augen-gneiss boulder. These have apparently been derived from the exposures of Scyelite on Carn Cas nan Gabhar, and lie in an E. 30 S. direction from the parent rock. Small morainic accumulations occur along the slopes in Strathrusdale.

Kincardine District.—In the Kincardine district there are extensive deposits of glacial drift, much of it of a morainic character and loose in texture. It appears to be thickest in the neighbourhood of the Easter Fearn Burn, east of Corriefearn. The main glaciation, as shown by striae on the solid rock, was from the W.N.W., and conspicuous hills in the low ground, as Church Hill and Cnoc Bad-a-Bhacaidh, have long and thick tails of drift on their lee or E.S.E. sides. In the lower part of the Carron Valley and elsewhere are many mounds of sand and gravel or kaims. A pretty set of such mounds occurs to the south-west of Blar Garvary, near Abhuinn a' Choire Bhuig, at a height of nearly 900 feet above the sea. Well formed moraines are very conspicuous to the west of Gradal on the Kincardine Burn. Many large boulders of the augen-gneiss occur along the Kincardine shore, and they are particularly numerous down the Wester and Easter Fearn Burns.

POST GLACIAL.

Both the 25-feet and the 100-feet raised beaches are well developed near Inverguseran, and between that place and Ailor. The 100-feet beach extends up Glean Ghuserein for two miles.

The Dornoch Frith is very shallow, and extensive modern deposits of mud are laid bare at low tides. Raised beaches are not conspicuous, except at the mouths of the principal streams. The 25-feet and 50-feet beaches can generally be traced on both sides of the Firth, but the 100-feet beach appears to be generally absent.

Dr. Crampton

Mr. Gunn.

Mr. Clough
and
Mr. Gunn

2. WEST HIGHLAND DISTRICT.—KNAPDALE, LORNE AND NORTH- WARDS TO LOCH EIL, SKYE.

Mr. B. N. Peach, F.R.S., District Geologist.

Mr. C. T. Clough,	} Geologists.
Mr. J. S. G. Wilson,	
Mr. H. Kynaston,	
Mr. A. Harker,	
Mr. C. B. Wedd,	
Mr. H. B. Muff,	

Work was carried on during the season in two separate regions. The chief district is on the mainland in the counties of Inverness and Argyle, and stretches from Loch Shiel in the north to the Crinan Canal on the south. The one-inch maps in which this area is comprised are 36, 37, 44, 45, 53, 54, 62. The other district is in the Islands of Skye and Soay in Sheets 70 and 71.

The principal Geological Formations and rock groups dealt with are :—Highland Metamorphic rocks, and associated gneisses; Torridon Sandstone; Metamorphosed Cambrian Dolomites; Lower Old Red Sandstone and associated volcanic and intrusive igneous rocks; Triassic, Jurassic and Cretaceous strata; Tertiary volcanic and intrusive igneous rocks; Glacial deposits; Raised Beaches, Peat, and Alluvium.

HIGHLAND METAMORPHIC ROCKS.

The region in which work was carried on in the Highland Metamorphic schists, under the supervision of Mr. B. N. Peach as District Geologist, stretches roughly along the west coast from Loch Shiel in the north to the Crinan Canal in the south. For convenience of description the region may be provisionally divided into two, viz. :—(a) one north of the Great Glen and the Linnhe Loch, and (b) one south of that line.

(a). *Region north of the Great Glen and the Linnhe Loch.*

Mr. Wilson.

Mr. Wilson is the only geologist who did field work in this district. The rocks in this region are chiefly schists of Moine type, and the muscovite-biotite gneiss. Though here described first in order it is not intended to imply that they are older than the schistose rocks south of the Great Glen. It has been shown in many former reports and *Summaries of Progress* that rocks of identical character with these occur over wide areas of country south of this line.

From his station at Corpach, Mr. Wilson continued fieldwork in Sheets 53 and 62, and mapped an area of 37 square miles, extending from a line drawn from the head of Loch Shiel south-west as far as the middle of Glen Scaddle, north-westwards to within a short distance of the upper end of Loch Shiel and the heads of Cona Glen and Glen Scaddle.

The whole of this district is mountainous, and the different kinds of rock produce a poor and very inferior soil. The flagstones weather so slowly that any soil produced by their denudation is at once removed by the various atmospheric denuding agents. Mr. Wilson.

The denudation of the muscovite-biotite gneiss to the west of the flagstones has produced very rugged and rough hill masses, which are either bare rock or else partially covered with a short, bright green herbage. This is due to the lodgement between the rock ledges and on the shelves of small and thin patches of light sandy soil derived from the disintegration of the gneiss. This soil is also scattered over the surface of the moraine slopes which cover the lower portions of these hills.

On both sides of Glen Scaddle the weathering of the foliated epidiorite has resulted in hills with long grassy slopes and rock ridges which culminate in sharp peaks. As this basic rock is much softer than the surrounding flagstones it has produced a considerable quantity of soil which is scattered over the lower hill slopes. This soil contains a small percentage of alkalies, etc., and as a natural result Glen Scaddle has the best grazing ground in this part of Argyleshire.

The larger portion of the grazing ground in North Ardgour is confined to the gravelly and sandy moraines, which are found in every valley and hillside. As the materials which compose these moraines are chiefly derived from the local rocks the grazing is only of a moderate quality.

Between the head of Loch Eil and Creggan there is a considerable belt of flat ground covered with deposits belonging to the 50-foot beach. When not covered by peat these haughs are fair grazing ground. The arable land is confined almost entirely to this raised beach on both sides of Loch Eil and the west side of Loch Linnhe. The crops grown by the crofters and on the farm lands include potatoes, oats, hay, with a few acres of turnips. With the exception of the hill pastures belonging to the various crofting townships the only grazing lands are confined to the lower portion of Glen Scaddle. All the remaining portion of North Ardgour has now been cleared of sheep and cattle and converted into deer forest.

To the south of the Creggan and Garvan, and in Glens Stronchreggan, Cona, and Scaddle, there are still to be found considerable remains of the old Caledonian Forest. Up to the beginning of the last century this part of Ardgour was covered with a forest growth, which was extensively cut down by the Bunawe Iron Co. and converted into charcoal, and shipped from Inverseaddle Bay to the iron furnace on Loch Etive. Large tracts of this country, which at present are barren moor, could be profitably planted up to a height of 1,000 feet.

There are no quarries or rock suitable for building purposes in this district.

The population is a scattered one, being confined chiefly to the crofting townships on Loch Eil and Loch Linnhe, and around Glen Finnan Railway Station. The stream water supply is good and abundant all over this district, but in no single instance has the abundant water power been utilised for industrial purposes.

Mr. Wilson.

The solid rocks which enter into the area are crystalline schists of Moine type, muscovite-biotite gneiss which form the "rocks of the country," and various igneous intrusions, some of which have been rendered schistose and metamorphosed, while others have retained their igneous structures, and are probably of later date than the metamorphism of the region.

The Moine schists or granulitic quartz schists with more or less felspar and mica form the south-eastern half of the area, and resemble the rocks described in former *Summaries of Progress* of which they are a continuation.*

The muscovite-biotite gneiss is a coarsely crystalline rock with muscovite and biotite in large flakes, and with quartz and felspar, which may be scattered either more or less regularly throughout, or may be arranged in layers, knots, and lenticles of varying size. The rock in places is flaggy and alternates with layers of granulitic quartz schist of Moine type, while in other places it becomes massive and coarse and assumes the appearance of a foliated igneous rock. In certain parts of the present area it is much traversed with knots, strings, and veins of quartzo-felspathic material, sometimes carrying muscovite or biotite, or even both micas, and the crystalline texture is often coarse, which in further descriptions will be named "pegmatites."

Rocks of the type of the muscovite-biotite gneiss, as above described, occupy nearly all the rest of the area surveyed; but this area is only the edge of a very wide belt of such rocks. A traverse was made along the line of the newly-constructed Mallaig railway while the rock cuttings were still fresh, and the muscovite-biotite gneiss belt was found to extend as far to the west as Kinlochailort station, the limit of the traverse, a distance of thirteen miles from the southern boundary of the belt. The direction of this section of railway is almost at right angles to the strike of the schists.

Igneous Rocks Associated with the Moine Schists and Muscovite-Biotite Gneiss.

Foliated Igneous Rocks.—Between Glen Scaddle and Cona Glen Mr. Wilson mapped the extension of the Glen Scaddle intrusive igneous complex and two small outlying masses within the area of the Moine schists. The rocks consist of foliated epidiorite with its marginal zone of granulitic gneiss like that described in former *Summaries*.† He also met with diorite and grey basic dykes of the same type as those described in the *Summary* for 1900.‡

Amphibolites and hornblende schists occur as sills and dykes in the muscovite-biotite gneiss.

* *Summary of Progress*, 1897, p. 65; *Ibid*, 1898, p. 40.

† *Summary of Progress* for 1898, pp. 40, 41; *Ibid*, 1899, pp. 45, 46.

‡ *Summary of Progress* for 1900, pp. 45, 46.

Later Igneous Dykes.—Between Glen Scaddle and Loch Eil, Mr. Wilson. Mr. Wilson dealt with unfoliated granite dykes cutting and altering the Moine schist of the types mentioned in previous *Summaries*.*

This year, dykes of a type of rock new to Scotland, which Dr. Flett describes as “Malchite,” probably connected with the later granites of the region, were discovered in the railway cuttings near the head of Loch Eil. The relation of these to the schist and foliated igneous rocks as seen in the railway cuttings is described in the sequel.

Dr. Flett adds the following summary of their characters:— Dr. Flett. “Certain of the dykes in Glen Finnan are Malchites, *i.e.*, fine grained grey dioritic dyke rocks, consisting of hornblende (green, turbid) and biotite. They include rocks which correspond exactly to the typical Malchites of the Odenwald as well as others which differ from these in several important respects.”

A few dolerite and basalt dykes of the ordinary type of Mr. Wilson. Tertiary age, and with a north-west trend, were met with throughout the area.

Sections exposed in Railway Cuttings east of Glen Finnan Station.—Between Glen Finnan station and Craigag (two miles) the newly-constructed Mallaig railway passes through a series of rock cuttings which afford excellent sections of the muscovite-biotite gneiss and its relations to the various igneous intrusions and pegmatites by which it is traversed. In these cuttings there is a considerable variation in the character of the gneiss. At the station the beds are very flaggy and micaceous, and contain a much larger percentage of muscovite than biotite, and are identical with the spangle-schist of the west of Ross-shire.† To the east of the station the beds become more flaggy and quartzose, being folded on a small scale on more or less vertical axes. Opposite the Roman Catholic chapel they contain several thin bands of zoisite-schist with wine-coloured garnets. In the cutting which forms the west approach to the viaduct across the Glen Finnan valley the rock is highly micaceous (chiefly biotite), and is intersected by numerous slip faults and small veins filled with quartz. Here the planes of foliation are often slickensided with chlorite, and the presence of chlorite appears to be entirely confined to the immediate vicinity of certain amphibolite masses and dykes which are associated with the schists at this point. On the eastern side of the viaduct the character of the gneiss changes, and for some distance it is a coarse massive banded grey and pink gneiss very similar to that of the eastern edge of the belt between Glen Scaddle and Cona Glen. On the west side of the county march and above the public road in Glen Callop, the rock is a coarse grey contorted muscovite-biotite gneiss chiefly composed of felspar with muscovite. Throughout the gneiss there are small detached strings and masses of pegmatite accompanied by thin

* *Summary of Progress*, 1897, pp. 65, 66.

† *Summary of Progress*, 1897, p. 56.

Mr. Wilson. irregular veins and masses of quartz. Iron pyrites is disseminated through the rock. On the east side of the county march several hard granulitic bands of quartzite are associated with the gneiss. Between the Craigag Lodge and the public road the muscovite-biotite gneiss is very similar in character to that portion on the west side of the viaduct, and has a large percentage of micaceous bands.

In the railway section already described the gneiss is intersected by a large number of dykes, sills, and masses of amphibolite, which never attain any great thickness. They are all foliated and appear to have been intruded into the muscovite-biotite gneiss prior to foliation. So entirely reconstructed are these igneous intrusions that it is now a matter of conjecture whether they were originally diorites, diabases, or gabbros. Many of these intrusions contain garnets which become larger and more numerous towards their edges, accompanied at the same time by a large increase of biotite. So characteristic is this increase of biotite that many of the smaller dykes are now entirely converted into a biotite-schist. The rock on both sides of the cutting at Craigag is intersected by several of these dykes, and one microscopically examined by Dr. Flett (9684), is described by him as a normal biotite-hornblende schist.

All these amphibolites are more or less cut by pegmatite veins, but it is a remarkable fact, that as these pegmatites approach an amphibolite mass or dyke, they sometimes disappear or else become very much attenuated where they traverse the amphibolite intrusions. Another interesting fact observed is, that when a muscovite pegmatite vein comes close to or intersects one of these amphibolites, biotite becomes the chief mica in the pegmatite for a short distance on both sides of the amphibolites.

In a cutting on the east side of the county march several foliated amphibolite dykes send branches along the planes of foliation of the gneiss, which appear to coincide with the original bedding planes of the sediments from which the schist is derived.

In this section the muscovite biotite gneiss is intersected by numerous pegmatites which vary in size from less than 1 inch up to 10 and 15 feet in breadth. These intersect the gneiss and amphibolites, and in some cases a few of them traverse thin malchite dykes in every direction. The large pegmatites to the west have a general direction of N.E. and S.W. As a rule they are unfoliated, and appear to have been introduced after the foliation of the gneiss. An exception has been noticed in one of the large pegmatites in the second cutting on the east side of the viaduct, where the vein has a rude foliation continuous in direction with that of the gneiss. These pegmatites are largely composed of felspar with quartz and muscovite mica (sometimes replaced by biotite) scattered through the felspathic base. On the east of the viaduct the small streaks and lenticles are all more or less parallel to the foliation of the gneiss, and in many cases, are cut by the larger pegmatites that cross the foliation planes. This seems to indicate that the pegmatites are of

different ages. The dyke-like pegmatites frequently cut one another, which shows that there were different periods of shattering and fissuring of the gneiss prior to their formation. The walls of these large pegmatites are clearly and sharply defined from the foliated gneiss, and the crystals of the different component minerals are often smaller next to the walls than in the rest of the vein. Mr. Wilson.

Malchite dykes traverse the muscovite biotite gneiss, amphibolite dykes and pegmatites. They are composed of a grey fine-grained holocrystalline rock, finest in grain next to the well-defined margins of the dykes. The breadth of these dykes varies from six inches up to six feet, and many of the smaller ones are slightly foliated. These are sometimes intersected by a few thin strings of pegmatite, which indicate that some of these "Malchites" were intruded towards the close of the period of the production of the pegmatites. In the second long cutting, to the east of the Glen Finnan Viaduct, there are five of the largest Malchite dykes between Glen Finnan Station and Craigag. In this section there are also several pegmatites measuring up to fifteen feet in breadth. These are cut at several points by Malchite dykes, but in no single instance was pegmatite observed to enter into them.

Region South of the Great Glen and the Linnhe Loch.

In addition to the tract already described, Mr. Wilson also surveyed a small area in Glen Nevis to the south of the Linnhe Loch. In continuation of his former work he traced the eastern boundary of the granite of Mullach Nan Coirean (*Summary of Progress* for 1899, p. 42), and the northern limit of the quartzite which forms the upper portions of Stob Ban and Sgor a Mhaim has also been mapped. This rock is a massive white quartzite with felspar. On the west side of Stob Ban, viewed from the east, it is seen to be folded twice on itself in a vertical distance of about 1,200 feet, the axial planes of the folds being nearly horizontal.

The biotite-schists (*Summary of Progress* for 1898, p. 47) which lie between the edge of the granite and the foot of the steep cone of Stob Ban are all contorted and folded more or less vertically. The quartzite dipping to S. and S.E. with an average angle of 35° seems to rest unconformably upon them. Several outliers of quartzite cap the north-west ridge of Stob Ban above Polldubh.

Loch Awe District.—With the view of finishing the survey of Mr. Kynaston Sheet 45, Mr. Kynaston visited some of the islands near the head of Loch Awe, with the following result:—

In completion of the Loch Awe area, Mr. Kynaston mapped the Island of Innischonian, near the head of Loch Awe, from Dalmally, and the small islands near Kilchurn Castle. The former consists of indurated black schists, with strong ribs of quartzite, and an occasional calcareous band. The schists are cut by a sill of hornblende porphyrite, and some small dykes of lamprophyre.

Mr.
Kynaston.

The smaller islands, near Kilchurn Castle, show the greenish phyllites and slaty beds of the Ardrishaig type, traversed by small sills of epidiorite.

Inliers in the Lorne district.—While mapping the Lower Old Red Volcanic plateau in the south-west corner of Sheet 45, several small inliers of crystalline-schists were observed by Mr. Kynaston and Mr. Peach. Of the areas surveyed by Mr. Kynaston, he reports:—

“In the area to the west and south-west of Loch Scamadale, inliers of the older rocks amongst the Lorne andesites, indicate the presence of pale grey and silvery phyllites of the Ardrishaig type. Again, two miles south-east of the head of Loch Scamadale, another inlier occurs, consisting of black slates with calcareous bands overlain by a coarse felspathic schistose grit or quartzite, of the ‘Loch Awe’ type, and intrusions of a coarse type of epidiorite, rich in felspar.”

Mr. Peach.

Extending north-eastward from Kilbride, about five miles south-east of Oban, there is an area, about a mile long and a few hundred yards in breadth, occupied by silvery grey phyllites, black-schists, and limestone, surrounded by the Lorne andesites. The limestone bands, which are thin, dark, crystalline and micaceous, are repeated by innumerable small isoclinal folds, the axial planes of which dip towards the S.S.E. The rocks are evidently the continuation of the limestone, the black-schist, and probably a small portion of the underlying phyllitic group met with in the Loch Awe region, the “Loch Awe group” of Mr. Hill.

Mr. Muff.

Lismore and adjacent Islands.—In order to complete Sheet 45, Mr. Muff mapped the north end of the Island of Lismore, and some of the surrounding islands and skerries, and has supplied the following report on the crystalline-schists.

By far the largest part of the north end of Lismore is composed of a dark blue limestone, which is sometimes argillaceous. The limestone is finely crystalline, and contains scattered cubes of pyrites. The argillaceous portions exhibit some sericitic mica on the bedding planes, and often alternate in thin beds with purer limestone. The limestone is thrown into folds of no great amplitude, whose axes run N.E., S.W., and very nearly parallel to the south-east coast. The folds, though commonly vertical, may be inclined to the N.W. or to the S.E., and their axes may pitch to the N.E. or to the S.W. The limbs of the folds are commonly rippled by smaller folds. In spite of this folding and crumpling, the limestone must have a considerable thickness.

The black-schist, with vertical planes of schistosity on which sericitic mica is developed, crops out chiefly on the west side of the island. It extends along the shore beneath the limestone, and runs up into the cliff in folds. Its position on the coast is often marked by an indentation of the shore line from which a depression runs inland, but in more than one case, the limestone is seen to arch over the slates, showing that the latter rock underlies the limestone. The junction between the slates and limestone is clear and well marked.

On Sliabh nam Ban-fionn, one mile W.S.W. of Port Ramsay, a Mr. Maff. breccia of considerable thickness rests on the limestone. It consists of angular and sub-angular limestone fragments, varying in size from small grains to blocks a foot or more across, lying in all positions in a limestone matrix. Some of these blocks are composed of contorted limestone, the folding of which appears to be anterior to the inclusion of the blocks in the breccia. A few pieces of black-schist occur here and there amongst the limestone fragments. On the shore, the breccia passes unconformably from the limestone on to the black-schist. The section is obscured somewhat by the intrusion of an igneous rock, referred to below, which has metamorphosed the rocks, and injected irregular veins into them in all directions. As to the age of the breccia, it is certainly of later date than the limestone and black-schist and it is cut by Tertiary basalt dykes and metamorphosed by the plutonic masses. The latter in some petrological characters resemble the igneous rocks of the Ben Cruachan complex, considered by Mr. Kynaston to be of Old Red Sandstone age. The breccia is provisionally placed amongst the schists.

Several small bosses of diorite, intruded into the schists, are surrounded by distinct aureoles of metamorphism. The black schist and limestone breccia are strongly hornfelsed. The purer limestone is altered to a whitish crystalline marble for several feet from the contact, whilst the argillaceous portions of the limestone have become a calc-silicate-hornfels. The chief soil on the surveyed portion of Lismore is derived from the boulder-clay, which forms a stiff clay soil with stones. Nearly all this ground, together with much that is covered by the gravels of the Raised Beach, forms arable land. Over areas not covered by boulder-clay, the folded limestone rises to the surface in long ridges and hummocks. It weathers along its exposed divisional planes, viz., bedding-planes and a perpendicular set of joints, forming more or less broken-down limestone-pavements comparable with the "clints" of the North of England Carboniferous Limestone. Along the lines of these widened bedding-planes and joints, there grows the bright green vegetation, which affords the pasture, for which the island is so well known, and which causes it to form such a striking contrast with the surrounding heather-clad mountains.

The limestone is now burnt for lime only at Port Ramsay, whence it is shipped to neighbouring coasts. Of the diorite masses, the one at the head of Allt a' Mhuilinn affords a better stone than the others, which are somewhat decomposed. The peat is not cut for fuel. The water supply is derived from springs which are abundant chiefly about the level of the 50-ft. beach. The gravel of the Raised Beach, owing to the springs, does not afford as dry a soil as might be expected.

The islands and skerries off the north and west coasts of Lismore, are composed of folded limestone and black-schist, traversed by dykes, which are similar to those of Lismore. Eilean Dubh, on the east, consists of white and yellow quartz-schist thrown into isoclinal folds, so that all the beds dip to the S.E.

Mr. Muff. The rock is mostly fine-grained, a few coarser beds alone containing small crushed quartz pebbles. At the southern end, the strike swings round from a N.E., S.W. direction to one slightly W. of N., and thin-bedded quartzite, with thin partings of green phyllite, appear.

Mr. Kynaston *Glen Creran*.—Proceeding towards the south-east a small area of crystalline schists was mapped by Mr. Kynaston in Glen Creran, in order to complete the survey of Sheet 45 (one inch) for publication. Mr. Kynaston reports as follows:—

“On the east side of the glen the ground rises to 3,000 feet on the granite ridge of Ben Sguliàird, on the west side to about 2,200 feet in the area occupied by the black-schists and quartzites. The river Creran flows through fertile alluvial flats, bounded by steep wooded slopes. The hills are mostly grassy, with but little heather, and so afford good pasturage. The soil on the hill sides is in many parts calcareous, from the weathering of limestone and calcareous hornfels; in other parts there is much sandy material from the weathering of the granite. The population is confined to the glen, and is devoted to sheep-farming and agriculture.

“In continuation of last year’s work, the area on the east side of Glen Creran was mapped up to the northern margin of Sheet 45, and the lines were carried on into Sheet 53 as far as Glenure. The schists of this area may be referred to the black-schists, grey phyllites with quartzose bands, and a banded calcareous series like that of the Pass of Brander, with occasional narrow zones of purer limestone. Intrusions of epidiorite are fairly common, but they are usually small and frequently behave rather as dykes than sills.

“The influence of the Ben Cruachan granite, which occupies all the higher ground on the east side of the glen, is distinctly noticeable in the schists, at a distance of nearly two miles from the granite margin. As we approach the granite, the schists become intensely hornfelsed, and constitute the continuation of the hornfels zone, which has been traced to this area from the head of Loch Awe and the Pass of Brander.”

Messrs.
Peach,
Wilson,
and Muff.

Kilmartin District.—In continuation of work done in former years by Messrs. Symes and Hill in the west of Argyleshire, Messrs. Peach, Wilson and Muff, during the autumn, mapped a small area of crystalline schists. The area, which is about two or three miles broad, extends from the western end of Loch Avich in the north, to the Crinan Loch on the south, being bounded on the west by the Barbreck River and Loch Craignish. It includes most of the islands in that loch. The northern part of the area was mapped by Mr. Peach. A small intermediate area lying along the boundary of Sheets 36 and 37 was surveyed by Mr. Muff. With the exception of one square mile at Slockavullin, south of Kilmartin, the rest of the area was mapped by Mr. Wilson.

The Kilmartin area is a portion of the low table-land into which this part of the west of Argyll is carved, irrespective of the nature of the rocks which enter into it.

Towards the S.S.W. the table-land is about 400 feet in general level, rising gradually towards the N.N.E. to over 1,000 feet, the highest point being attained in Carn Duchara, which is over 1,700 feet in height. This part of the table-land is carved into a series of parallel rocky ridges with a N.N.E. and S.S.W. trend, corresponding to the outcrops of sheets of epidiorite constantly repeated by folding, which resist the weather more effectually than the sedimentary rocks into which they were intruded as sills. The two principal streams which drain the area are the Barbreck River, running into the head of Loch Craignish, and the Kilmartin Burn, a tributary of the Add. Both of these run along the strike in wide valleys, the lower parts of which are hollowed down to below sea level and which are continued seawards as sea lochs. Terraces of alluvium and various raised beaches are found in the lower part of both valleys. The high alluvial terraces of the Kilmartin Burn being partly due to water which drained out of Loch Awe at a period when the upper end of the loch was obstructed by glacier ice and the temporary outlet of the loch was at the S.W. or Ford end. The side streams are necessarily short and steep, and often run along lines of fault or along the courses of basalt dykes, which traverse the area in a N.W. and S.E. direction in great numbers. It is along these lines also that the few narrow passes that cross the area are found.

Messrs.
Peach,
Wilson, and
Muff.

The table-land is for the most part occupied by rock, but there are a few patches of Boulder Clay and morainic drift, the moraines being only found near the head of the Barbreck River, and on the plateau south of Loch Avich. As a rule the hollows on the table-land correspond with the outcrops of schist of sedimentary origin and are floored with peat or swamps, and an occasional small loch. In the higher regions a thick swathing of peat covers almost the whole surface except the rocky hill tops and escarpments.

The decomposition of the epidiorite gives rise to a scanty soil which, where not covered by peat, supports a grassy vegetation while the peat and quartzite give rise to heath and bents. The higher part of the table-land is, therefore, entirely given over to sheep and grouse moor, while a few Highland cattle are reared. The steeper slopes are often covered with grassy vegetation, especially where, in addition to the *débris* of the epidiorite, the underlying rock is limestone. These slopes are infested with innumerable rabbits, which are trapped and sent to the market in great numbers.

Cultivation is now almost entirely confined to the alluvial terraces and the raised beaches, and is mainly directed to the wintering of the live stock. It has been much more extensive at no distant period and carried well up the slopes, especially where limestone and decomposing epidiorite form the subsoil. Even yet these old cultivated spots form the best grazing grounds in the whole district. In this, as well as in nearly every district in the West Highlands, these patches of old cultivation are over-run with the common bracken *Pteris aquilina*, which is spreading to an enormous extent and spoiling wide tracts of good pasture.

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The population is chiefly confined to the lower parts of the valleys, and is thicker than in most parts of the West Highlands, the mixed grazing and cultivation which the region affords having formed an attraction ever since the first of the Gaels colonised the region early in the present era.

The schistose rocks entering into the area consist of phyllites, limestones, and quartzites, of sedimentary origin, with sheets and dykes of epidiorite and chloritic schists, some of which have undoubtedly been intrusive igneous rocks, and others may probably have been lava flows.

As the area on its eastern border is contiguous with that mapped by Mr. Hill in former years, and as his lines have been continued into the present area, there can be no doubt that the rocks represent Mr. Hill's "Loch Awe Series," and part of the "Ardrishaig Phyllites." It was found desirable to sub-divide the rocks of sedimentary origin further than was carried out by Mr. Hill. The natural grouping of these rocks and their order of succession appears to be as follows:—

- (e) Quartzite. Fine grained above and passing down into a coarse pebbly grit below, the pebbles consisting chiefly of quartz, many of them of bluish tinge, and a considerable number of felspar. One small pebble of graphic granite was found by Mr. Muff. The matrix of the grit in places becomes highly calcareous and the rock in places passes down into the following
- (d) Pebbly Limestone. A dark limestone more or less sandy throughout, with pebbles of quartz and felspar identical with those found in (e), and with fragments of black limestone, phyllite, black-schist, a few well-rounded pebbles of fine-grained quartzite an inch or two in diameter. In places the limestone becomes a breccia of dark limestone and black-schist fragments.
- (c) Limestone. Dark fine-grained crystalline limestone in thin layers intercalated with dark calcareous slates or phyllites.
- (b) Black slates and phyllites interleaved with light-coloured siliceous bands and grey phyllites, and passing down by gradual intercalations of grey phyllites into
- (a) Grey and green silky phyllites, some of which are sandy.

The rocks of sedimentary origin occupy scarcely half the area, the rest being occupied by epidiorites and later igneous intrusions. Both the schists and epidiorites are thrown into a succession of sharp folds, the long axes of which run approximately N.N.E. and S.S.W. Both limbs of most of the folds dip towards the S.S.E., but there are a few exceptions to this rule where the folds are normal. As well as this minor folding the rocks are arranged on a larger scale in a compound anticline along the eastern border of the area, while the rest of the area forms part of a compound syncline. The result of this structure is that the grey and green phyllites (a) are mostly to be found along the ridge forming the watershed between Loch Awe and Glen Domhain and Loch Avich. Passing westwards from this line these rocks alternate with the dark phyllites (b) and limestones (c), while the pebbly limestones (d) and the quartzites (e) are the chief rocks met with in the centre and west of the area. While this is the general disposition of the rocks,

however, the lower rocks frequently show themselves even in the central and western part of the area on the crests of the sharper minor anticlines, so that the whole series cannot be a thick one, even with the addition of the epidiorite sills. Messrs. Peach, Wilson, and Muff.

During the mapping of the area a considerable amount of evidence was obtained to show that the quartzite (e) and the pebbly limestone (d) are unconformable to the limestone (c), the black slates (b), and the grey phyllites (a). The nature of the evidence is twofold. First, the pebbly limestone (d) often contains fragments of the dark limestone (c) and dark phyllites (b), where the two rocks are adjacent to each other, and the bottom beds of the pebbly limestone (d) sometimes consist of a breccia of these two rocks. Grey silky phyllite fragments, like those of group (a), also occur both in the limestone and the quartzite. There can be no doubt, therefore, of the derivative nature of the bed, while in numerous sections the pebbly limestone (d) is seen to shade up through calcareous grits into the quartzite (e). Second, the quartzite, which usually overlies the pebbly limestone, in places overlaps it and rests on the black slates (b) and limestones (c), and even on the grey phyllites (a). The calcareous grit or pebbly limestone also transgresses the edges of the underlying rocks in places. The evidence, therefore, is very much in favour of an unconformability between the quartzite and pebbly limestone on the one side, and the limestones and phyllites on the other.

Epidiorites, occurring chiefly as wide spread sills folded with the sedimentary schists, occupy more than half the area. Two different types can be made out on the ground:—

1. A fine-grained rock, slaggy and highly vesicular at its margin, sometimes showing an arrangement of phacoids with vesicular outer layer and a non-vesicular interior suggestive of the "pillow structure," visible in certain lava flows. Sills of this rock are usually associated with the phyllites and limestones and apparently produce little or no metamorphic action upon the neighbouring sedimentary rocks. In part of the area they are continuous with rocks already reported on by Mr. Symes (*Summary of Progress* 1899, pp. 61, 62) and Mr. Kynaston. Their likeness to certain basic lavas has been noted by Mr. Teall (*ibid. Summary of Progress*, 1900, pp. 33, 42, 44, and footnote p. 34).

2. A more massive rock, coarse in texture, and with few or no vesicles. These sills are usually associated with the limestones and quartzites, and produce a certain amount of contact metamorphism, converting the impure limestones into calc-silicate hornfels. A sill which extends over a considerable area in Glen Domhain, where it is intruded into the quartzites, is so full of large porphyritic feldspars that it looks as if it had been an andesitic rock prior to its alteration. All the epidiorites are in places more or less foliated, and chlorite, epidote, and zoisite are the most common minerals. All are more or less calcareous, and in the slaggy portions the amygdules of calcite make up half the bulk of the rock. The microscopic characters of the above type of rocks have been already given in Mr. Kynaston's report for 1900. *Summary of Progress* for 1900, pp. 32-35. Mr. Hill has also described the characters of these rocks as developed in ground adjacent to the present area. *Summary of Progress*, 1900, pp. 41, 42.

Crush, or pseudo-conglomerates were observed by Messrs. Peach, Wilson, and Muff in ground mapped by them respectively. They occur generally where the pebbly limestone is associated

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with sills of epidiorite. From the fact that what appear to have been continuous bands of shale are now represented by rows of isolated phacoids or **S**-shaped masses of slate in a pebbly limestone matrix, we are inclined to accept Mr. Hill's explanation for part, at least, of the phenomenon. Mr. Muff, who has mapped the best examples, gives the following description of what occurs in his area.

Mr. Muff.

"The structure described by Mr. J. B. Hill, under the name of 'crush conglomerates,' has been met with in several localities in the pebbly limestones usually near the junction of that rock with epidiorite. More or less lenticular blocks of epidiorite, whose long axes are approximately parallel, lie inclined at high angles to the line of junction. The best exposure occurs at a cliff 1,200 yards north by east of Salachary. Two undulating bands of phacoidal masses of epidiorite, commonly between six inches and one foot in length, and with highly inclined long axes, cross the face of the pebbly limestone. A third, but shorter, belt is composed of phacoids of black slate embedded in the limestone." Mr. Muff is also of opinion that some of the vesicular phacoids found in the fine-grained epidiorite may have had a similar origin. He reports on them as follows:—"An Samhladh, and the ground to the north-east is composed of folded schistose epidiorite, which contains bands of uncrushed vesicles filled with calcite. In many places, lenticular masses, up to two feet in length, consisting of an outer coat of vesicular epidiorite, and an inner core of more schistose epidiorite, lie with vertical long axes, in schistose epidiorite, the planes of schistosity of which conform more or less to the edge of the lenticular masses. It is possible that these lenticular masses have been formed by the nipping off of the crests of the folds composed of an outer coat of highly vesicular and an inner core of strongly schistose epidiorite."

TORRIDONIAN.

Mr. Clough.

Island of Soay.—In order to complete the Survey of Sheet 70 (one inch), Mr. Clough undertook the mapping of the Torridonian rocks of the Island of Soay, and has supplied the following report:—

"The Island of Soay, though nearly all composed of bare rock and peat, is conveniently situated for the herring and the lobster fishing. The population is consequently not so sparse as in many parts of the Highlands, and it diminishes in summer, as many of the younger men are then away, engaged on yachts and tourist steamers.

"The island is essentially composed of Torridonian rocks, and of Tertiary intrusions. The Torridonian rocks dip somewhat steadily W. at about 15°, and are not altered nor veined with quartz, and there is nothing to suggest folding or thrusting. They are divisible into three groups, which are as follows, beginning at the top:—

"1. Leac Faoileann group. Pale pink, rather fine-grained false-bedded grits. Thickness about 270 feet. Top not seen. Mr. Clough.

"2. Beinn Bhreac group. Red and purplish red false-bedded grits, with pebbles from half an inch to two inches long, of quartzite, felsite, andesite, and jasper. Thickness about 2,200 feet.

"3. Leac-Stearnan group. Pale pink false-bedded grits, with thin bands of grey sandy shale. Thickness about 900 feet. Base not seen.

"The rocks in group 2 closely resemble those in the Applecross group of the mainland."

A large N.W. fault cuts the island in two, with a downthrow on the N.E. side about 700 feet. This fault does not appear to affect the plateau basalts on the north side of the Sound of Soay, and it is probably of pre-Tertiary age. Another fault, tending N.N.W., passes a little east of Beinn Bhreac, and has a downthrow to E.N.E. of about 90 feet. The fault seems of earlier date than a thin sill of porphyritic basalt. Various other faults can also be proved to have taken place prior to certain igneous intrusions.

Isle of Skye.—Mr. Wedd, while mapping the Secondary rocks in the Sconser, Loch Sligachan, and in the Strathaird Districts of Skye for the completion of Sheet 71, met with some small inliers of Torridonian rocks. Owing to their isolation there is no direct evidence as to the exact subdivision of the formation they belong to, but there is no doubt as to their Torridonian age. Of these inliers Mr. Wedd reports as follows:— Mr. Wedd.

"Near Sconser, this sandstone, hard and compact, sometimes coarse and pebbly, either pink and felspathic or light grey, lies in an anticlinal fold on and below the northern slope of Glamaig. It is brought up again further west by N.W. faults at Glac Fhearna. In Strathaird, Torridon rocks occur at Camasunerie. They consist in part of hard, fine, and coarse-grained, compact sandstone, often pebbly, and changing irregularly from light grey to pink, with many grains and pebbles of felspar, and of very hard finely laminated shales. At Camasunerie the shales occur only as thin layers in the sandstone, but west of Camasunerie they form thick beds underlying massive sandstone. The relation of these thick shales to the rest of the Torridon sandstone of Camasunerie is obscure."

CAMBRIAN.

Metamorphosed Cambrian dolomites of Strath in Skye.—A re-examination of the metamorphosed equivalents of the Durness Limestone group in Skye became desirable in the light of Mr. Teall's work on the similar rocks at Ledbeg in Sutherland and Dr. Pollard's chemical investigations published in the *Summary of Progress* for 1900. The metamorphism is exceptionally well displayed in the vicinity of the Tertiary granite and gabbro of the Broadford district. Accordingly Mr. Harker revisited these localities in conjunction with Mr. Tait, who collected a typical series of specimens. Mr. Harker.

The results go to show that the rocks must have been in great part dolomitized, and often completely, prior to the igneous intrusions, and have been more or less completely dedolomitized

Mr. Harker. by metamorphism in the manner described by Mr. Teall (*l.c.* pp 153, 154). The dolomite has been reduced to calcite, the magnesia giving rise to other minerals. A common type among the resulting marbles is a rock consisting of calcite and forsterite, the latter often in perfect crystals, which show prominently on a weathered face. From this type come also at least the majority of the serpentinous marbles or "ophicalcites" of the district, the serpentine being derived from forsterite, which is often seen partially destroyed. Other minerals found in varieties of the marbles are diopside, tremolite, white mica, idocrase, and a violet spinel. Such rocks must have been originally impure, chiefly owing to disseminated chert, but pure dolomites have also been dedolomitized. The result in this case is a pure white rock consisting simply of calcite and brucite, and comparable with the "pencatite" of Predazzo in the Tirol. It seems probable that periclase was first formed, and has been converted to brucite by hydration; but neither periclase crystals nor unmistakable pseudomorphs after them have been detected.

LOWER OLD RED SANDSTONE.

**Messrs.
Peach and
Kynaston.**

District of Lorne.—In order to complete Sheet 45 (one inch) with a view to its publication, the remaining unsurveyed portion of the Lorne Volcanic Plateau, which enters into that sheet, was mapped by Messrs. Peach and Kynaston during the season.

In the autumn and early winter, Mr. Peach, in intervals between other duties, mapped a small area round Loch Nell and the head of Loch Feochan.

Mr. Peach.

Feochan Area.—The area surveyed by Mr. B. N. Peach during the year is part of the Lorne Volcanic Plateau which here rises to a general level of over 500 feet, the greatest height being over 900 feet. The plateau is trenched almost to sea-level by the two branches of the Feochan River which runs into the head of the sea loch of the same name. The floors of the valleys in which the rivers run are flat and their sides steep showing a step-like series of escarpments corresponding to the outcrops of the successive lava flows. The side streams join the main valleys through deep straight-cut ravines, which coincide either with lines of fault or with igneous dykes, the shattered rocks and decomposing dykes being more readily removed by the streams than the more solid andesitic lavas which they traverse.

The surface of the plateau is for the most part very irregular and almost bare of drift but, in some of the hollows and flats, there is a sparse coating of morainic material which is usually covered with peat and gives rise to a heathy vegetation. Above the general level there rise irregular rocky tops with the characteristic stair-like escarpments. Towards the western portion of the ground, the surface of both the flats and the rocky hillocks is dotted with moraines. Some well-defined trains of boulders are strewn across the ground and can be traced up to their parent rocks, which always lie to the westward of the trains, while the

sources of others, such as those of the Cruachan granite blocks, **Mr. Peach.** lie outside the present area. The varied conditions of the plateau give rise to a mixed vegetation favourable for sheep grazing and for summer grazing for the hardier varieties of young cattle and horses. On the sides of the valley and between the escarpments where the slopes are not too steep, the disintegrated igneous rocks produce a thin soil which gives rise to a scanty but sweet vegetation, affording summer grazing for cattle and sheep; while the cultivation is almost entirely restricted to the alluvial lands and the raised beaches which floor the valleys, but the ground is at present cropped mainly to support the live stock. Dairy farming is carried on by some of the farmers as there is a great demand for milk during the tourist and yachting season at Oban, which is within easy reach. The population which is entirely occupied in farming, is sparse and confined to the valleys.

The climate is mild and wet, and as there are several lochs along the course of the streams there is a constant supply of good water both summer and winter. Copious springs issue on the sides and bottoms of the valleys, chiefly from the fault-breccias and lines of dykes which traverse the andesites in large numbers.

Trees, both conifers and hardwoods, grow luxuriantly where sheltered from the sea winds, even upon the steep *débris* covered hill-sides, and sometimes on the rocky escarpments themselves.

The andesitic lavas supply material for drystone dykes and rubble for masonry, and the harder varieties afford good road metal, but the best road metal is obtained from the dolerite and basalt dykes which traverse the area in great profusion. The numerous boulders of Cruachan granite which are strewn over some parts of the area afford excellent material for corner stones, lintels, and such work where massive stones are required.

The raised beaches and alluvial deposits afford a good supply of gravel and sand for concrete and mortar.

Peat occurs in considerable amount both on the plateau and on the 100-foot raised beach, but is not at present much worked as coal is found to be more economical.

The prevailing rocks in this area are andesitic lavas, some coarse conglomerates, and fine tuff and basement conglomerates, and red and grey shales.

These rocks are arranged as follows: The basement conglomerates, overlain by red and grey shales like those of Oban, here rise on a low dome from beneath the andesites at the south end of Loch Nell and are visible on both sides of the loch. In the high plateau lying between Loch Nell and the foot of Glen Lonan, and the Feochan Bheag, the grey shales are succeeded by andesitic lavas which dip gently to the south and east from off the dome, being only separated from each other, in most cases, by their own slaggy upper and under surfaces, and forming a succession of craggy escarpments. One thin zone of agglomerate, tuff, and red shale, lying at a level of 300—400 feet from the base, has been traced from Torr an Tuire near the head of Loch Nell, by Barnacarry and Kilmore to near Kilbride. Above this zone shattery

Mr. Peach. fine-grained andesite flows form successive escarpments for a few hundred feet, and are then succeeded by massive coarse porphyritic hypersthene-andesites which cap the highest ground and cross the area from Kilmore to Glen Lonan. Lava flows of this type are succeeded to the east of the present area by a zone of mica-andesites of more acid character, which were mapped by Mr. Kynaston and are described by him.

In the small area south of the head of Loch Fechoan mapped by Mr. Peach, successive flows of basic andesite dip gently towards the north-west.

Both of the above areas are traversed by dykes of hornblende-porphyrite, quartz-felsite, and lamprophyre, of the same general age as the lava-flows. This appears to be the northern edge of a zone where the dykes are increasing in number southwards from the present area. Both the lavas and these dykes are cut by numerous basic and acid dykes with a north-west and south-east trend which are probably of Tertiary age.

Mr. Kynaston *District between Taynuilt and Loch Scamadale.*—This area consists almost entirely of hilly ground, rising to a height of nearly 1,700 feet above sea-level, and is occupied by the Lorne volcanic series. It constitutes essentially a denuded lava-plateau, intersected by small, though often steep-sided glens. The slopes of the hills are often terraced by well-marked lines of crag and escarpment indicating the outcrop of successive flows, while the higher ground frequently forms an uneven heather-covered table-land, throughout which numerous knolls and crags of rock stand out among peaty and marshy hollows.

The lavas, especially the more basic types, are usually much decomposed and disintegrated, and break off readily into small angular fragments. The rock takes on a yellowish or brownish crust, and is purple, or sometimes brick red on fracture, in contrast to the almost black colour of the fresher varieties.

The soil is thin and poor, almost the entire area being given up to grouse moors, and sheep pasturage. The only portions under cultivation are the alluvial flats in the glens, and the raised beaches and river terraces, where the soil is good and fertile.

The rock is often quarried for road metal, and for stone walls, and occasionally for building purposes.

The population is restricted to the glens and the low ground near sea-level.

In the Taynuilt area the general dip of the volcanic series is south-east, and it is often possible to map out individual flows and trace them for some distance. To the west of Taynuilt a considerable area is occupied by a dark purple andesite, with porphyritic crystals of plagioclase and greenish pseudomorphs after hypersthene. This rock is well seen in a roadside quarry, $1\frac{1}{2}$ miles north-west of Taynuilt, also in Airds Park, whence it may be followed across the wooded ground to the south-west to the conspicuous hill of Deadh Choimhead, on the north side of Glen Lonan. Apparently beneath this flow we find in Airds Park a much more acid type of rock, similar to the felsitic lavas

of Glen Nant, described in the *Annual Summary* for 1897, Mr. Kynaston p. 84. As in Glen Nant we have here also a finely banded structure due to flow, and the occasional occurrence of a coarsely spherulitic or nodular variety, with numerous nodular bodies up to about half-an-inch in diameter. The same rock is again well seen south-west of Taynuilt, to the west and north-west of Balindore, and forms the wooded knoll west of Barguilean. Flow brecciation is occasionally seen, and there is, as in Glen Nant, a frequent association with hornblende and mica andesites. To the south of Taynuilt and on the west side of Glen Nant, the felsitic lava is again well exposed at and near Taylor's Leap, together with hornblende- and mica-andesites.

Beneath the felsitic lava there is a dark grey compact andesite, which appears to cover a considerable area immediately to the south-west of the Taynuilt raised beach. This is a more basic type of lava than the hypersthene andesite, noticed above, only rarely showing porphyritic feldspars and containing numerous specks of the reddish-brown mineral (? iddingsite) which occurs mostly as pseudomorphs after olivine. Beneath this basic flow we find conglomerates with some red shales and gritty beds, seen in numerous exposures south-west of Taynuilt. The conglomerate shows a high proportion of quartzite boulders, andesite boulders being also common, though more local.

Interbedded with the basic andesite of Airds Park, N.N.W. of Taynuilt, we have a band of an acid tuff. It is compact and flinty in texture and varies in colour from reddish-purple to a pale yellowish. It is often crowded with small fragments of felsite, with some of andesite, and shows biotite flakes and crystals of an acid feldspar. A precisely similar tuff is again seen in the higher ground further south, cropping out below the upper crags of Cruach Ard-dhuine, where it is intercalated between narrow bands of red shale and sandstone.

The lavas, both above and below the bands of sediment, are of a basic facies, and may be referred to either feldspathic types of olivine-basalt or a very basic andesite. The lower flow rests upon conglomerate, and is highly vesicular towards its upper portion.

Farther to the south-west, and in the area south of the upper part of Glen Lonan, the normal lava is a somewhat basic andesite, which, in the higher part of the area, is capped by a well-marked flow of mica-andesite. This latter constitutes the upper part of Carn Gaibhre, and stands out conspicuously in the crags of Creag-an-Fhithich to the south. It is again well seen on the south side of Beinn Ghlas, and covers a considerable area to the north-west of Lochan Dubha. The rock is often felsitic and shows flow-banding. Flow-brecciation is also very common, numerous angular felsitic fragments being embedded in a reddish matrix. The rocks which overlie the mica-andesite are well seen in a crag section half-a-mile north of Lochan Dubha. Resting upon it we have a flow of basic andesite, allied to basalt, above which is a well-marked band of andesitic agglomerate and ashy material, overlying which is a purple porphyritic (?) hypersthene-andesite.

Mr. Kynaston The agglomerate appears again on the west side of Lochan Dubha and is well exposed in the conspicuous Creag Mhor, south-east of Kilbride in Glen Feochan, and has been followed for some distance above the mica-andesites on the south side of Glen Lonan. Its fragments consist entirely of different varieties of andesite in a finely fragmental matrix. They are occasionally more or less rounded and often attain a diameter of 4 or 5 feet.

The basic lava below the agglomerate is often highly vesicular, the vesicles being represented by amygdules, often as large as hens' eggs, of reddish agate with an inner layer of crystalline quartz.

South of Kilbride, in Glen Feochan, the high ground (Creag Ghlasrach, Righ Roc, etc.) consists of a dark purple porphyritic andesite, with numerous phenocrysts of plagioclase and a green mineral, probably a pseudomorph after hypersthene. The rock is often very vesicular, but the non-vesicular portions often closely resemble the intrusive porphyrites, owing to the comparatively large size of the phenocrysts and the reddish colour of the weathered surface. This type of flow covers a considerable area south of Kilbride, and is continued to the north side of Loch Scamadale.

Further east, in the region about the Sior Lochs and Beinn Dearg, east and south-east of Musdale, considerable masses of tuff have been mapped and were seen to be bedded between rather basic types of andesite. This is a rather less acid tuff than that of Airds Point and Cruach Arddhuine, and is similar to the rock mapped by Mr. Symes near Achnacloich, and by myself near Taynuilt and already described.*

Mr. Peach. The volcanic rocks in this area must rest on a very irregular floor of older rocks, for an elongated inlier of black shales and limestones (see *ante*, p. 124) rises from beneath the porphyritic lavas near Kilbride, which must be separated from the basement rocks visible on Loch Nell by a thickness of more than 1,000 feet of basic lava flows, the edges of which must abut against this old floor of schistose rocks.

Mr. Kynaston Inliers of the older rocks are seen in several places in the area about Loch Scamadale, one to the south-east of the head of the loch, above Fineglen, occurring at an altitude of over 1,100 feet, and forming the bed and slopes of a portion of the glen. These inliers afford interesting evidence of the kind of surface over which the lavas were poured out.

An important result of the mapping has been the recognition of the wide distribution of more acid types of lava-flow, such as hornblende- and mica-andesites and felsites, and various pyroclastic rocks. This may serve to connect the Lorne series with that of the Blackmount and Glencoe, where the more acid types are a characteristic feature. We may note, too, the not infrequent observation of basic having succeeded more acid material.

* "On some Tuffs associated with the Andesitic Lavas of Lorne." *Trans. Edin. Geol. Soc.*, vol. viii., p. 87.

In the *Summary of Progress* last year, p. 71, Mr. Kynaston described the induration noticeable in the andesites and conglomerates as they are followed towards the Pass of Brander. This year he obtained further evidence of a similar kind at the north-west end of the Pass. Thus, in the railway cutting close to the Awe Viaduct, intercalated in the andesites, is a band of laminated shales and grits, the induration of which is very marked. The granite is not more than three-quarters of a mile from these beds, a distance at which it may well have indurated the sediments without appreciably affecting the andesites. At the entrance to the Pass of Brander the andesites are well exposed on the south-west side, and appear to be decidedly indurated, and show small veins and bands, a few inches in breadth, of a rock allied to porphyrite, but approaching microgranite in texture. Above the cliffs on this side there is a band of conglomerate and grit, which again shows decided induration.

Dykes and Sills.—Dykes and sills, belonging to the same volcanic period as the lava-flows, are exceedingly numerous throughout the greater part of the area mapped, and maintain, as a rule, the usual N.N.E. and S.S.W. trend. The mapping has shown that the area most thickly intersected by these intrusions constitutes a kind of belt or zone, about a mile in breadth, stretching from the area immediately south of Taynuilt to the high ground south of Loch Scamadale. The intrusions are mainly hornblende- and biotite-porphyrates, similar to those described in former reports. Occasionally more basic types are found, often closely resembling the normal andesitic lavas, while more acid varieties have affinities to quartz-porphyry. Intrusions of quartz-porphyry, cutting the andesites, have been mapped in several places in the area S.W. of Taynuilt, and closely resemble those occasionally associated with the Ben Cruachan granite.

Dykes allied to lamprophyre have also been observed, though they are not common. North-east of Loch Scamadale a dyke occurs closely resembling a mica-diorite. Another dyke, of unusual type in this district, occurs in Glen Nant, a quarter of a mile south of Tailor's Leap. The rock is allied to the hyperites, and may be termed a hypersthene-diorite-porphyrite. It shows under the microscope [9652], large phenocrysts of zoned plagioclase, idiomorphic hypersthene altered to bastite, and pale greenish augite, in a granular ground-mass of plagioclase with some alkali-felspar and a little quartz. Such dykes form connecting links between the andesitic lavas, and the hyperite modifications of the granites.

Kingshouse area (Blackmount and Royal Forests).—This area is a wild mountainous tract, the highest point of which rises to slightly over 3,600 feet, and is occupied by the Blackmount and Glencoe volcanic series and granite. On the east, the wide stretches of peat, and moraines of the Moor of Rannoch, are in striking contrast to the conspicuous heights about the head of Glen Etive and Glencoe.

Among the volcanic rocks, the hornblende-andesite weathers with a pale grey or whitish crust, and forms conspicuous crags,

Mr. Kynaston often much broken up by joints, so producing much scree material. The breccia and agglomerate is more massive, and weathers into comparatively more rounded masses with a rough surface, and breaking away in large angular blocks. The felsite forms striking precipitous crags, with well-marked vertical joints, and disintegrates into sharp angular flinty fragments. The granite forms rounded hill-tops, often flanked by steep crags with characteristic jointing.

To the east lies the western portion of the Moor of Rannoch—a table-land with a granite floor, weathering to a fine quartzose sand, covered by moraines and peat-mosses, while in the hollows lie numerous lochs and lochans, showing varying degrees of silting up. The peat, where of good quality, is used for fuel, also the numerous stumps of Scotch fir which occur in it so abundantly.

There is no cultivation, the ground being entirely deer forest.

Volcanic Rocks.—The mapping of the volcanic area to the north of the Clach Leathad was continued by Mr. Kynaston during June from Kingshouse. The principal types of rock which constitute the volcanic series have already been described in the *Summary of Progress* for last year, so it will be sufficient here to give a summary of the more recent progress of the work as regards the behaviour and relationships of the rock-masses, with a brief account of certain fresh facts of interest. The mapping of the rhyolitic felsites, breccias, and hornblende-andesites of the long north and south ridge, on the north side of the Clach Leathad, was completed. The andesites occupy the highest ground and form a roughly oval area, invaded on its south and west sides by the Blackmount granite. The rocks are mostly typical hornblende-andesites, though augite-bearing varieties also sometimes occur. On the north and east sides of Stob Glas Choire a zone of 20 to 30 feet of dark grey laminated shales and grits was found intercalated in the andesites. The beds are much indurated by the granite. Below the andesites we find the breccias, apparently underlying them in a normally bedded manner. In its upper portion the breccia is often of finer material, and occasionally shows gritty bands, and well-marked signs of bedding. The breccias sweep round the northern margin of the andesites, capping the ridge at Sron Creise, and thence bend round to the south-west and are cut off by the granite. While examining the breccias in detail in two or three places, Mr. Kynaston found fragments of a rather acid biotite-granite, resembling that of the Clach Leathad. That they were derived from the granite of the Blackmount is, however, not possible, since this latter is clearly itself intrusive in the breccias.

The rhyolitic felsites are seen apparently underlying the breccias on the north-east spurs of Stob Glas Choire and below the summit of Sron Creise. They rise up in precipitous crags on either side of the Càrn Ghleann, and thence stretch north-westwards, below Sron Creise, to the river Etive, being terminated abruptly to the south-west by the intrusion of the granite. From the river Etive the felsites were traced further north-west and

were found to be continuous with the felsitic masses of the Buachaille Etive Mor. Along its north-east margin the felsite shows a sharply defined junction with the older schists. The contact face of the igneous rock is usually vertical or almost so, and behaves apparently as an intrusive rock, and often shows a narrow border of breccia. Outside the margin, small oval-shaped and dyke-like intrusions of the felsite are common in the schists, and in the Càrn Ghleann occur two small plug-like intrusions of augite-andesite. Mr. Kynaston

Passing to the Buachaille Etive Mor, on the north-west side of Glen Etive and west of Kingshouse, we find evidences of bedding well indicated. Thus at the foot of the north-east crags of Stob Dearg the base of the series is formed by a bed of conglomerate (15 feet), resting upon the schists, and overlain by reddish and purple shales. Above the shales lie bedded conglomerate and breccia, which are overlain by the rhyolitic felsites. Practically the whole of the east face of Stob Dearg consists of different varieties of felsites. The rocks show a most perfect flow structure, and flow-brecciation is common. About half-way up the east face a band of dark purplish and greenish shales is seen in the felsites, and coincides with part of an obliquely descending line of feature called the "Crowberry Traverse." These beds are again well seen in the bed of the gully immediately south-east of this feature. On the north side of Stob Dearg the breccias are well bedded and contain gritty bands.

The intercalations of sediment above described closely resemble, both lithologically and in mode of occurrence, the sedimentary bands so common among the lavas of Lorne, and constitute strong evidence that the volcanic series of the Blackmount and Royal Forests is of the same age as that of Lorne. The shales of the "Crowberry Traverse" closely resemble the indurated sediments seen in the railway cutting near the Pass of Brander.

As already stated, the granite of the Blackmount is seen cutting each member of the volcanic series along the western slopes of the Sron Creise ridge. The contacts are remarkably clear, and the evidence of the alteration of the volcanic rocks has been established beyond any room for doubt, both in the field and with the microscope. Veins of granite and pegmatite are sometimes seen traversing both the andesites and the breccias, and the granite veins occasionally contain fragments of the breccia. It is obvious, therefore, that the fragments of granite in the breccia must evidently have been derived from an older granite mass, or may indicate an earlier plutonic phase belonging to the same period of igneous activity. A parallel case may be found in the occurrence of fragments of granite and gabbro, in the agglomerates of the Cuillin Hills of Skye.*

* See Harker, "The Sequence of the Tertiary Rocks of Skye," *Geol. Mag.*, Dec. 4, vol. viii., p. 507.

Mr. Kynaston *Dykes*.—The final period of eruptive activity was marked by the formation of numerous dykes, with the normal N.N.E. and S.S.W. trend. These are mostly of hornblende and mica-porphyrity, but quartz-porphyrity and andesite are not uncommon. The resemblance between these dykes and the similar types of intrusion which cut the Lorne andesites and the Ben Cruachan granite, is so close, and their behaviour and intimate association with acid and intermediate lavas and plutonic masses so similar, that one can hardly doubt that they belong to the same period of vulcanicity. Intrusions of lamprophyres, or allied rocks, are comparatively rare, only one case having been noticed this season, namely of a rather basic rock allied to camptonite, cutting the schist on the north slopes of Sron Creise.

Glen Creran, Ben Cruachan Granite.—The mapping of the western margin of this granite was continued by Mr. Kynaston from Glen Creran, and the boundary line was traced from Coire Buidhe, east of the head of Loch Creran, along the western slopes of Ben Sguliaird to the upper part of Glenure. The larger portion of the rock is a biotite granite, relatively poor in hornblende, while a more acid pink granite is frequently exposed on the higher ridges of Ben Sguliaird. Inclusions of hornfels are common.

In the upper part of Glenure, N.N.E. of Ben Sguliaird, is a mass of augite-diorite, of a type formerly observed in Glen Strae. It extends from the south bank of the river Ure up to the granite margin on the slopes of Ben Sguliaird. It does not pass into the granite, but appears to be interbanded with it in a rather complicated manner. The same rock is again seen along the granite margin on the north side of An Grianan, and doubtless represents a more basic modification of the same magma from which the granite was derived.

Associated dykes in the Glen Creran area, as yet mapped, are confined to a few small lamprophyres.

Mr. Muff *Lismore Granite Masses*.—During the mapping of the metamorphic rocks in the north of the Island of Lismore, in Sheet 45 (one inch), Mr. Muff met with several small bosses of plutonic rock in which were represented several rock types similar to or identical with those found round the margin of the "Cruachan" massit. These are associated with a similar set of dykes like those surrounding the Cruachan area. Both sets of rocks are in turn cut by one or more types of Tertiary basic dyke. A strong presumption is, therefore, raised that these rocks belong to the same general period of intrusion as the Cruachan granite.

Mr. Muff supplies the following description of these bosses and dykes in Lismore :—

"Four plutonic bosses of small size appear within the area. The first forms a small promontory on the west side of the island a quarter of a mile north of Sliabh nam Ban-fionn. Its form, as shown in the cliffs, is that of a blunt cone with concave slopes. A second boss rises as a dome-shaped hill immediately N.E. of

Sliabh nam Banfionn. A third occupies the circular hollow at the head of Allt a' Mhuilinn, and is surrounded by high walls of altered limestone. It is crossed by a Tertiary basalt dyke. Two small outcrops on the side of the large peat moss at Sron-na-Craoibhe probably belong to a fourth boss.

The rock composing these bosses appears to be typically a medium grained augite-diorite, usually with abundant biotite. Hornblende often surrounds the pyroxene and a very little quartz is present. A specimen from the head of Allt a Mhuilinn containing rather more quartz and abundant orthoclase, shows a passage to the tonalites. The boss near Sron-na-braoibhe and that a quarter of a mile N. of Sliabh nam Ban-fionn exhibit basic marginal varieties. A specimen from the latter (10,106) described by Dr. Flett as "an augite-biotite-diorite-porphyrte, shows large idiomorphic phenocrysts of pale green pyroxene, abundant porphyritic biotite less perfectly formed, remains of serpentine after olivine, and a ground-mass of hypidiomorphic plagioclase and orthoclase. In some respects it resembles a kentallenite." Several small veins of aplite which contain an unusual amount of plagioclase cut this basic margin of the boss, but basic varieties are not always present along the margins. Near the contact of the boss mentioned second above with the limestone breccia, a fine-grained augite-porphyrte is seen. The latter has injected abundant irregular veins into the former, whilst the igneous rock is crowded with fragments of limestone and limestone-breccia. All these bosses are accompanied by aureoles of metamorphism which are narrow in the purer limestone, but broaden out in the argillaceous limestone and black schist. The purer limestone is converted into a whitish marble for several feet from the contact, whilst the impure limestone forms a calc-silicate-hornfels.

Amongst the numerous dykes, it appears possible to recognise (1) a set of N.E. lamprophyre dykes, (2) irregular mica lamprophyre dykes, (3) a set of dykes varying in composition from basalts to andesites which traverse the island from W.N.W. to E.S.E. and are probably of Tertiary age. The north-easterly lamprophyre dykes appear to be vogesites. They are very irregular, sometimes appearing as branching dykes, sometimes as a string of lenticular masses, end to end. A certain small amount of movement appears to have taken place subsequent to their intrusion. On the low promontory immediately west of Port Ramsay, and elsewhere, the W.N.W. basaltic dykes cut them. It has not been shown that these lamprophyre dykes cut the plutonic masses, but apparently they enter the aureole of metamorphism without undergoing alteration.

The mica-lamprophyre dykes include the largest dykes in the area, the best examples appearing on Eilean Ramsay and the neighbouring skerries. It cannot be said that they follow any particular direction. They are younger than the plutonic masses, for not only is an unaltered dyke seen to penetrate the metamorphosed limestone, but small lamprophyre veins cut the diorite.

Mr. Peach. *Glen Domhain Granite*.—While mapping the crystalline schists in Glen Domhain, near the edge of Sheets 36 and 37 (one inch), Mr. Peach traced for over a mile the southern and eastern boundary of the granite mass mentioned by Mr. Symes in the *Summary of Progress* for 1900, p. 49. The mass is fine grained near its edge, and often of a rather basic type, resembling the hyperites that are found near the margins of the Galloway granite masses. The alteration in the schists and epidiorites is intense close up to the granite, but dies out within a comparatively short distance, and is similar to that described in former summaries.*

TRIASSIC.

Mr. Wedd. *Isle of Skye*.—In order to complete the mapping of the Secondary formations in that part of the Island of Skye which enters into Sheet 71, Mr. Wedd resumed the work of last year, as reported in *Summary of Progress*, 1890, p. 113. His work was carried on in four separate districts—(1) Sconser, on Loch Sligachan; (2) Strollamus and south of Scalpay; (3) Strathaird and Torran; and (4) the district of Strath between Lochs Slapin and Eishort.

Rocks of Triassic age were met with in two of these localities, viz., Sconser and Strathaird. About Sconser they consist of conglomerate, made up of pebbles of Durness (Cambrian) limestone and chert and Torridon sandstone, red sandstone, and red and light green marly beds, the conglomerate predominating near the base. At the top there is often a bed of hard fine-grained light green sandstone. In this area these rocks are often much metamorphosed. At a point 300 yards E. of the second milestone from Sligachan in a burn section some thin, soft, light marly sandstone lying between two igneous sills, overlying a hard, coarse, blue-streaked grit, and underlying the lowest Lias limestone, may probably represent the thin beds provisionally assigned to the Rhætic in Strath.†

In the district of Strathaird (3) a thin quartz conglomerate occurs at the S. end of Blath Bheinn. On the west side of its southern spur, a thin blue limestone conglomerate is visible beneath the base of the highly metamorphosed Lias. These conglomeratic beds probably both belong to the same group as the beds assigned to the Trias which occur elsewhere in Skye.

JURASSIC.

LOWER LIAS.

Isle of Skye.—The Lower Lias in the Sconser district consists of thick micaceous shales and beds of calcareous micaceous sandstone, both with *Arietite* Ammonites and *Gryphæa arcuata*. Below these is a thin series of blue limestones, with shale near the top, two coral beds near top and bottom, bands of *Gryphæa*

* *Summary of Progress* for 1899, p. 63; *Ibid*, for 1898, p. 86.

† *Summary of Progress* for 1900, p. 113.

near the top, and a bed of small oysters near the base. The limestones are perhaps not much more than 30 feet in thickness. No separate division of calc-sandstone at the base can be recognised as in the Broadford beds, neither can the sandstone which immediately overlies the limestones be found. The *Bucklandi* and *Semi-costatus* beds are recognisable. In district (3), N. of Torran, highly metamorphosed blue limestones with beds of shales in the upper part, and possibly a coral bed, dip steeply towards the S. and S.W. from off the granophyre on either side of the Strath Beag. They are succeeded by thick micaceous shales with sandy beds, considerably metamorphosed. The shales contain obscure ammonites and pectens, not yet determined, and in the upper part, beds of *Gryphaea*. It is clear that here is the lower part of the Lias, but it is difficult to say how far up in the series the strata extend. In Strathaird, N. of Camasunerie, Lower Lias occupies the upper part of the valley of Abhuinn near Leac, and forms the lower slopes on the E. and W. sides of the south spur of Blath Bheinn. It is intensely metamorphosed by the plutonic rocks, and also by innumerable dykes. It consists of thick shales and sandstones overlying thin blue limestones intercalated with shales and containing bands of *Gryphaea* with thicker limestone below. The whole is highly metamorphosed, but the few traces of ammonites obtained, together with the beds of *Gryphaea*, are enough to show the Lower Liassic age of the series. A little patch of the same limestone was seen near the mouth of Abhuinn Camas Fhionnairidh. In the Strath district (4) Lower Lias has been mapped, as usual a thick series of micaceous shales and micaceous sandstones with *Gryphaea*, &c., above thin blue limestones with thin shales, along the east shore of Loch Slapin and the north shore of Loch Eishort. The *Bucklandi* and *Semi-costatus* beds are recognisable.

UPPER LIAS.

Isle of Skye.—A small exposure of Upper Lias was noted by Mr. Tait at one point on the east coast of Strathaird beneath the shingle of the beach, while he was collecting from the lowest beds of the Inferior Oolite. It contains abundant Ammonites of the *Communis* and *Serpentinus* groups.

INFERIOR OOLITE.

Isle of Skye.—In the Sconser district (1) a massive strip of white sandstone is seen at intervals on the north shore of Loch Sligachan. Below Torr Mor it passes up into shaly sandstone and sandy micaceous shale with a bed of impure graphite above. As no fossils were procured Mr. Wedd is unable to say to what part of the Oolitic series the beds belong, as they are completely isolated and no great thickness is seen. In the district of Strollamus (2) very thick metamorphosed white sandstones, laminated in the lower part, form the coast and eastern slopes of Glas Bheinn Bheag. Calcareous doggers occur and seem to contain obscure belemnites. In the upper part are one or two beds of shale and of

Mr. Wedd. highly calcareous sandstone or sandy limestone altered to sandy marble. A comparison of the whole sequence at Strollamus together with evidence from the sandstone itself and from the fossils of the overlying series, clearly shows that these metamorphosed sandstones are the Inferior Oolite of Strathaird. The intrusion of the granophyre mass of Beinn na Cro and Glas Bheinn Bheag reverses the dip in anticlinal form between the two localities. In Strathaird a thick series of sandstones, more or less calcareous, white at the surface but blue when fresh, and often passing in the lower parts into beds of gritty blue limestone, forms the whole of the eastern side of the peninsula. Beds of *Avicula*, *Pecten*, *Terebratula* and *Rhynchonella* occur at several horizons. As these beds overlie the Upper Lias and pass up into the Great Estuarine series, they clearly comprise the Inferior Oolite, but whether they include any higher horizon or not depends upon whether the lower part of the Great Estuarine series is strictly homotaxial or not with the Great Oolite. A bed of black pyritous shale of variable thickness separates some 30 or 40 feet of white sandstone at the top from the sandstones below. The shale is marine and contains locally, badly preserved impressions of ammonites, but no clearly determinable specimen has been obtained. The Inferior Oolite sandstones can be recognised in a highly metamorphosed state on the east flank of Sgurr nan Each near the head of Loch Slapin.

GREAT OOLITE (*Loch Staffin Series*).

Isle of Skye.—At Strollamus (2) the thick sandstones are succeeded by a series of shales and sandy limestones; both are often crowded with small bivalves (*Cyrena*?). Beds of dwarf oysters also occur, resembling *Ostrea hebridica*. The series is comparable in its main features with the Great Oolite of Strathaird. In Strathaird (3) the Great Oolite consists of a thick series of—

- g. Blue shales and mudstones, with calcareous concretions.
- f. Smooth, muddy blue limestones, weathering buff, with beds of *Paludina scotica*, intercalated shales and bands of "beef."
- e. Shales with small lamellibranchs (*Cyrena*?).
- d. Calcareous shales or shaly limestones crowded with *Ostrea hebridica*.
- c. Black shales.
- b. Blue sandy limestones full of small lamellibranchs (*Cyrena*?).
- a. Black laminated shales crowded with the same bivalves (*Cyrena*?).

The series undoubtedly belongs to the Great Estuarine series. The lower part, with the oyster beds, is recognisable in a metamorphosed state on the east flank of Sgurr nan Each and above the west side of the south end of Strath Mor.

OXFORDIAN.

At Strollamus (2) the shales with limestones are succeeded by marine shales with cordate ammonites; these shales must consequently be assigned to the Oxford Clay. On the

opposite coast of Scalpay, in the valley of Allt Stapaig, the Mr. Wedd. following sequence is seen, the beds dipping E.S.E. or S.E. as at Strollamus:—

		Feet.
Cretaceous	{	Metamorphosed cherts (?) sandstone passing under lava.
	{	Metamorphosed blue limestone with cherts (?) - about 8
	{	Blue pebbly calcareous grit with <i>Pecten asper</i> and <i>Exogyra</i>
	{	cf. <i>conica</i> - - - - - 2
Gap of a few feet.		
Oxfordian (?)	{	Black laminated shales with indeterminable ammonites and belemnites
or Kimeridgian (?)		

The ammonites in these shales, though too obscure for definite determination, on the whole somewhat suggest an Oxfordian or Kimeridgian horizon. As Oxford clay undoubtedly overlies the Great Estuarine series at Strollamus just opposite, it seems that these black shales probably belong to an Oxfordian or Kimeridgian horizon. In Strathaird (3) a thick series of grey micaceous shales, with thick calcareous-micaceous shaly sandstones in the lower part, cover the Great Oolite and underlie nearly the whole of the Tertiary lavas. At the base, a conglomerate of large round pebbles of white quartzite or metamorphosed white sandstone in a matrix of calc-shaly-mica-sandstone sometimes occurs. In the lower beds, cordate ammonites are locally abundant, together with large belemnites, *Pecten fibrosus*, occasionally a large *Gryphaea*, and much fossil wood. These beds undoubtedly belong to the Oxford clay, but as no fossils were found in the upper part, it is uncertain whether any Corallian or Kimeridgian horizon is present. At the top, in one place, a small outcrop of blue limestone was seen, gritty below, with pebbles of sandstone of local Oxfordian type.

CRETACEOUS.

Scalpay.—From the south of Scalpay (2), in the valley of Allt Stapaig, fossils from the thin grit above mentioned as overlying the black shales with ammonites were submitted to Mr. Newton and Dr. Kitchin, who at once suggested the resemblance of certain *Pecten*s to *P. asper* of the Upper Greensand. This determination has since been confirmed: casts of an *Exogyra* seem to belong to *E. conica*, and a *Spondylus* may also be represented by casts. There is no doubt as to the Cretaceous age of these beds. The overlying blue limestone bed can be traced far inland in Scalpay, where it is pinched in between the granophyre and the Torridon Sandstone.

A similar blue limestone overlies the Oxfordian shales at Strollamus and may also be Cretaceous, but this needs confirmation. The same may be said of a bed of limestone seen in one place to overlie the Oxfordian shales of Strathaird (3).

Mr. Clough.

Isle of Skye.—On the south coast of Skye a small patch of Mesozoic rocks emerges from beneath the plateau basalts between a quarter and half a mile of the foot of Allt nan Leac. This patch lies on the north side of the Sound of Soay and a little west of that referred to in previous years by Sir A. Geikie* and Mr. Harker.† It includes a considerable thickness of the *Gryphæa* beds of the Lias, and, above these, come red and green, apparently glauconitic sandstones, with occasional pebbles. In some sections the sandstones appear unconformable to the *Gryphæa* beds, but in others they are conformable. In the best section they appear to be conformable, they are about fifty feet thick, and are overlain by a chert-grit horizon, about three feet thick, in which are thin courses and lenticles of chert embedded in a gritty rock. When examined with a hand lens the chert shows many spicules and other remains of micro-organisms. Above the chert-grit horizon come two or three feet of shale with small lumps of dark chert.

In one place near the exposures of chert *in situ* there is an agglomerate which probably belongs to a small volcanic vent older than the plateau basalts. In the agglomerate there are many lumps of chert like that *in situ*, and containing similar spicules and micro-organisms. There are also many pieces of chert (?) with red cores.

Mr. E. T. Newton has examined thin slices of the cherts from the beds *in situ* and also those in the agglomerate, and he finds them very similar. The organic remains are much obscured by chalcedonic deposits, but it is clear that besides the abundant sponge spicules, foraminifera are present, both Textularian forms and others, including *Globigerina* (?). Some of the specimens also show fragments of echinoderm plates and serpulæ tubes. Mr. Newton considers there is little room for doubt that the cherts are of Cretaceous age, and that they have a closer resemblance to Greensand chert than to those discovered in Arran.‡

Dr. G. J. Hinde has also examined the specimens and agrees with Mr. Newton's views.

The nearest rocks of Cretaceous age that are at present known occur under the plateau basalts of Morven and Mull, at distances of forty and fifty miles.

Mr. Wedd.

Geological Structure of the Secondary Rocks of Skye.—The above rocks seem to be arranged as follows:—Near Seonser (1) the strata are thrown into an anticlinal fold with axis running E.N.E. It is intersected by numerous faults generally with north-west direction and north-east downthrow. At Strollamus (2) the lower beds have a general E.S.E. dip from off the granophyre of Glas Bheinn Bheag, and their general dip is maintained throughout the local Jurassic series; several faults occur, but their position is often conjectural owing

* *Summary of Progress* for 1898, p. 137.

† *Summary of Progress* for 1899, p. 142.

‡ *Summary of Progress* for 1900, pp. 123, 169.

to the presence of much drift. In Strathaird (3) the Jurassic Mr. Wedd. rocks are almost free from faults, except in the north, where there is much faulting. On the west side of the peninsula an important fault runs from the east side of the Camas Fhionnairaidh N.N.E. up the valley of Abhainn nan Leac. It throws down Great Oolite on the east against Torridon rocks and overlying Lias on the west. It is evidently pre-Tertiary and post-Jurassic. East of it, throughout Strathaird (3) the Tertiary lavas rest on Oxford clay or slightly overlap on to the Great Oolite, while west of the fault the lava lies on Lower Lias or Torridon Sandstone. The fault has considerable stratigraphical significance, for throughout the south of Skye, its line of continuation to the N.N.E. marks the re-appearance of Trias and Lower Lias on the west. This fault truncates the western side of a shallow syncline, which occupies the greater part of Strathaird. West of the fault a narrow anticline runs along the west flank of the valley of Abhainn nan Leac and further north along the east flank of Sgurr nan Each and beyond it. West of the anticline another syncline is shown in the Lias of Blath Bheinn. Between Loch Slapin and Loch Eishort the Trias and Lower Lias lie in a gentle syncline.

TERTIARY.

Igneous Rocks of Skye.—Mr. Harker was occupied during Mr. Harker. the field-season chiefly in mapping the basaltic plateaux on the west side of the Isle of Skye, between Loch Bracadale and Loch Brittle (Sheet 70, one inch). The area surveyed during the year on the western side of Skye forms part of an extensive region, throughout which like physical conditions rule. This region consists of an assemblage of deeply eroded plateaux carved out of the Tertiary basaltic group, which is a succession of basic lavas alternating with basic sills. It is thus a country of strong relief, but with extremely little variety of lithological characters. The climatic conditions, determined by the situation and the prevailing winds, are also strongly marked. The precipitation is very heavy, and storms are frequent, but the winter temperature is not severe.

Except where escarpments or crags of the more resistant rocks break through, the surface of the country is in general covered more or less thickly with peat. This covering has in great measure protected the subjacent rocks, which had previously been stripped and scoured by the ice of the glacial period, and it results that over most of the country, soil and subsoil are alike wanting. This moorland ground is given over to sheep-farming, and affords good pasturage. The slopes are roughly drained by surface cuts, where the shape of the ground is favourable, but the more level stretches, which form the flat watersheds and border the principal streams, are in the condition of bog. The peat is cut for fuel, but at present only by the crofters for their own needs. Reclamation has never been attempted except on a very small scale, and there is little prospect of any successful effort in this direction.

Mr. Harker. Cultivation of any kind is practicable only on certain narrow strips of the lower ground. On the slopes of some parts of the main valleys, and also sometimes of the narrower sea-lochs, which are submerged valleys, the boulder-clay attains some thickness, and comes to consist of a reddish loam, or sandy clay, representing the waste of the basaltic rocks. Most of the crofts occupy these situations, while others are placed on the relics of raised beaches which fringe some sheltered portions of the coast. Potatoes and oats are raised; the latter a scanty crop, which ripens late, or in some years not at all. The small size of some of the crofts, and the inequalities of the surface, render the use of horses for ploughing difficult in many cases, and the ancient *caschrom* or foot-plough may still be seen at work in the more remote places. The manure in general use is sea-weed. Owing to the heavy annual rainfall in this region the soil speedily becomes robbed of its more soluble constituents, and in any attempt at cultivation of a systematic kind, the choice of suitable fertilisers would be a prime condition of success.

Here, as elsewhere, the volcanic group is found to consist of numerous alternations of basic lavas and intrusive sills, also of basic composition. The lavas present somewhat more variety than in the districts formerly mapped. The amygdules in them sometimes attain a large size, and contain a profusion of zeolitic minerals, often very perfectly crystallized. Another interesting feature is the not infrequent occurrence of bands of red clay (plinthite) due to the surface of a lava-flow having suffered subaërial weathering before it was covered by the next succeeding flow. Only rarely is the monotony of the succession broken by lenticular patches of volcanic agglomerate, indicating the neighbourhood of small vents now concealed. In one coast-section, near Dùnan Earr an Sgùirr, occurs a fluvatile deposit, some thirty feet in thickness, marking part of the course of one of the rivers of the volcanic epoch, and consisting of alternations of conglomerate and bedded tuff. The pebbles are of granite and Torridonian grit, rocks nowhere exposed in this part of Skye.

The regularly stratiform intrusive sills of dolerite intercalated among the lavas make up more than half of the total thickness, and, owing to their superior durability, form all the prominent features of the landscape. They have in this district a very general vertical prismatic jointing. In particular, the isolated hills Preshal More and Preshal Beg, near Talisker, afford a magnificent display of regular columnar structure.

The great majority of the sills are not porphyritic in the ordinary sense, but some enclose sparingly scattered crystals of felspar of conspicuous dimensions. One sill of peculiar character is well exhibited in a small isolated hill (crowned by a Dùn) about two miles north of Talisker. It is about 100 feet thick, and the upper and principal portion is crowded with large porphyritic felspars, but lower down these become rarer, and at the base they disappear entirely, while the rock assumes in other respects a different character. A comparison is suggested with certain

composite double sills formerly noted on Roineval and elsewhere; but in the present instance there is no sharp dividing line between the upper and lower portions of the sill.

While mapping the small area of Liassic and Cretaceous strata Mr. Clough. already referred to (*ante* page 146) as occurring on the north side of Soay Sound, Mr. Clough found an agglomerate with fragments of chert, containing sponge spicules and micro-organisms similar to that found *in situ*, near at hand, and which Mr. Newton considers to be probably of Greensand age. Mr. Clough is of opinion that the agglomerate "belongs to a small vent older than the plateau basalt." In addition to the fossiliferous cherts, the agglomerate contains many pieces of chert with red cores, the exact nature of which is doubtful.

Island of Soay.—The intrusive rocks in the Island of Soay are regarded by Mr. Clough as of Tertiary age. Perhaps the earliest intrusion is the small elongated mass with flattish top which forms Dubh Sgeir, which is a peridotite. It is in part crowded with inclusions of troctolite, some as much as 18 inches long, and is crossed by two N.N.W. dykes.

The other intrusions form dykes, running N.W. or N.N.W. as a rule, or sills. Many of the dykes and sills are rich in olivine, and some of the sills consist of dunite or picrite. These highly basic rocks frequently cut others of dolerite or basalt.

There are a number of sills of porphyritic basalt, and in these the felspar phenocrysts near the centre are often two or three inches long, and one or two broad. Rarely they are as much as eight inches long, and four broad. These phenocrysts invariably diminish in size near the margins of the sill, and for three or four inches next the selvage they usually disappear. This seems to indicate that the phenocrysts are not strangers in the rock, but have been developed *in situ*. Similar phenomena are observed on the course of a long dyke of porphyritic basalt which crosses the E. side of the island in a nearly N. direction.

Near several of the intrusions the Torridonian grits have been partially vitrified into buchite.

Inverness-shire and Argyleshire.—Dykes with a general N.W. Messrs.
Peach,
Wilson, and
Muff. and S.E. trend are more or less numerous in all the areas mapped in this region during the season. These vary from highly basic olivine basalts to trachytes and even rhyolites. As they traverse all the rocks, as well as most of the structures above described they are considered to be of Tertiary age.

A few basalt or dolerite dykes of this age were met with by Mr. Wilson in the area mapped by him north of the Great Glen.

Mr. Muff traced dykes of two types, viz:—dolerites and hornblende-andesites, across the northern end of the island of Lismore. The relative dates of intrusion of these two types is doubtful, but Mr. Muff formed the impression that at least one of the andesite dykes traversed a dolerite dyke.

In the district south of Oban (Sheet 45) dykes of this age become more numerous. East of Kilbride they all appear to be basic in composition; but to the south of Loch Feochan there is

Messrs.
Peach,
Wilson and
Muff

a belt of country about a mile wide where compound dykes occur, in which successive rocks of increasing acidity from olivine basalt up to rhyolites have welled up one and the same fissure. Several of the fissures can be shown to have been used as an escape for gases after they had been filled by one or more of the earlier molten intrusions, as they are partially filled with agglomerate and tuff made up of thin fragments of these rocks as well as those of the walls of the fissure, and through this agglomerate some of the more acid rhyolites can be seen to have risen. A very good example of such a dyke is exposed within a few yards of the road along the south shore of Loch Feochan, about one-third of a mile from its head. The oldest rock filling the fissure is an olivine basalt. This is pierced by a massive dolerite dyke which exhibits chilled edges against the basalt. The dolerite and the basalt are traversed by fissures filled in with agglomerate of their fragments and lastly a dyke of rhyolite with double pyramids of quartz and showing fine fluxion structure along its edges, cuts both the basalt and the agglomerate.

One of these compound dykes, stretching from the head of Loch Feochan to near the head of Loch Scamadale and extending further south with the same trend, swells out at irregular intervals into a succession of wide internodes partly filled with fragmental and partly with molten materials, which evidently represent a series of volcanic vents arranged along the line of fissure. One of these vents was observed by Mr. Symes and reported on previously. (*Summary of Progress for 1898*, pp. 153, 154.)

In several instances the trachytes and rhyolites form simple dykes which traverse the andesite lavas of Lower Old Red Age, which form the "rocks of the country." In others these acid dykes are seen to converge with basic ones and unite to form compound dykes like those described above.

Mr. Kynaston

In the south-western portion of Sheet 45 the Lower Old Red lavas are intersected by numerous Tertiary dykes, mostly with the direction N.W. and S. E. The larger proportion of these belong to the dolerites and basalts, while along a certain zone a set of acid dykes have also been mapped. The basic intrusions are exceedingly numerous and vary greatly in breadth. The breadth, too, of an individual dyke often varies considerably, and their course may be sometimes diverted from the normal along older lines of faulting. Petrologically the rocks vary from a medium-grained dolerite to olivine basalt, or tachylite in thin bands. In some places a more felspathic type of dyke occurs, suggesting affinities to an intermediate type, such as trachyte. Compound dykes, consisting of two or three varieties of intrusion, running side by side in the same fissure, are common.

The acid dykes are well seen in the Loch Scamadale area. They are mostly pale grey felsites or rhyolites, occasionally with porphyritic quartz and felspar, but often too decomposed for satisfactory examination. They exhibit a well-marked flow structure, and often break up, on weathering, like a mass of slate, parallel to the wall of the dyke. They frequently split up the

basic dykes, or form compound dykes along with them. A well-
marked line of such compound intrusions runs along the course of
the Braglenmore burn, south-east of the head of Loch Scamadale,
and is continued to the north-west in the direction of Kilmore in
Glenfeochan. (*Ante* p. 150.) Along this line a feature of special
interest is the frequent occurrence of masses of ash and agglom-
erate, consisting of fragments of basalt, felsite, and andesite,
evidently indicating a line of volcanic vents of an explosive type.
The ashy material occurs in roughly oval-shaped masses, break-
ing through the andesites, or as bands bordering the acid dykes.
Occasionally the ash is seen to be cut by the acid intrusions.

Mr. Kynaston

KILMARTIN DISTRICT.

Kilmartin District.—In Kilmartin district, lying between
Loch Avich and Loch Crinan, mapped by Messrs. Peach, Wilson
and Muff, during the season, basic dykes of this age with a
generally N.W. and S.E. trend are extremely numerous. In the
northern half of the area as many as thirty may be crossed in
a traverse of a mile in a N.E. and S.W. direction. They vary in
thickness from several yards to a foot or so, and in texture and
composition from coarse-grained olivine-dolerites to fine-grained
rocks, which probably include andesites. Some of the more basic
varieties show tachylite margins, and some are vitreous through-
out. Many of the more andesite-like dykes have glassy cores,
with a more or less broad selvage of rocky texture; but a few are
glassy throughout. That they are not all of one and the same date
of intrusion is shown by the fact that at Port an Deora, a little to
the N.W. of Duntroon Old Castle, Mr. Wilson observed a N.W.
dyke which cuts through another dyke of coarse dolerite which,
in this part of its course, trends nearly E. and W., the later dyke
showing chilled edges against the dolerite. Compound dykes also
occur.

Messrs.
Peach,
Wilson and
Muff.

Mr. Muff observed one of the less basic dykes to converge with a
dolerite dyke and run beside it for some distance within the one
fissure without crossing the latter. Two compound dykes
were traced by Mr. Wilson inwards from near the head of Loch
Craignish, one through Loch Fearphuirn and the other through
Strome, which are believed by him to be the continuation of two
dykes mentioned in last year's *Summary* by Mr. Symes as
crossing the Craignish Peninsula on the other side of the loch.*

Alteration produced by the Tertiary Intrusive rocks in Skye. Mr. Harker.
—Mr. Harker has supplied an account of the dedolomitization
of the Cambrian dolomites of the Strath district of Skye by the
Tertiary Plutonic masses. (*Ante* p. 131.)

Mr. Barrow also furnishes an interesting account of the effects
of the Tertiary dykes upon the clastic mica flakes in the Lias
clays of the Heast district.

Mr. Barrow.

* *Summary of Progress* for 1900, p. 127.

Mr. Barrow. The Lias shales of Skye, like those of Yorkshire, contain numerous large flakes of mica. They are so much cut up by dolerite dykes that it interferes with the mapping of the area. The effect upon the micas in the shales, close to their contact, is similar to that produced upon the micas of the Yorkshire Lias by the Cleveland dyke, only, in the present case, a dyke 10 yards across destroys the micas for at least 6 inches from its edge, which is more than that produced by the Cleveland dyke where it is 50 yards wide. This greater alteration may be due to the igneous material being nearer its source of origin and so having a higher initial temperature; or it may be due to the fact that the intrusions were so numerous as to heat the Lias more than we suppose, and so leaving less work for each particular intrusion to do. It should be recognised that these shales may be raised to a high temperature without leaving any evidence that they have been so. Mr. Maynard Hutchings has proved by experiment that a moist clay, enclosed in a steel cylinder, may be kept at a dull red heat for weeks without the slightest sign of alteration being produced on it that can be recognised, even by the aid of a microscope. The lithology of the lowest beds of the Lias promises to be more than usually interesting; and the alteration of these beds by small intrusions seems to be equally so. A large number of specimens have consequently been collected to investigate these points as soon as time permits.

Mr. Clough. Mr. Clough observed that the Torridonian arkoses in the Island of Soay were glazed and altered along the margin of the Tertiary dykes and intrusive sills producing Buchite. Similar phenomena occur in Applecross and Islay where Torridonian arkoses are traversed by Tertiary basic dykes.

Pleistocene, including Glaciation and Glacial deposits.

Island of Soay.—In the Island of Soay there are no widespread drift deposits, but scattered boulders of rocks, chiefly freestone, granophyre and gabbro, foreign to the island, are common. There are also rare boulders of mica-schist and hornblendic gneiss. Glacial striæ are numerous, and most of them run nearly E. and W. The N.E. corner of the island, near Clachan Uaine, has been invaded for a little distance by a drift almost entirely composed of blocks, often of very large size, of gabbro and troctolite. These blocks must have travelled from the Cuillin Hills of Skye, and perhaps they were carried to their present position after the ice from the mainland of Inverness-shire had dwindled to such an extent that it no longer reached Skye.

Mr. Wilson. *Glen Nevis.*—In Glen Nevis, Mr. Wilson obtained evidence as to the amount of drift deposits which must have been removed by denudation since the later phases of the glaciation of this region. A series of pot-holes were observed on the steep glaciated cliffs that bound the gorge made by the River Nevis at a point a mile below Steall, and a short distance beyond the point to which the coaches

run. The highest of these is 275 feet above the present level of Mr. Wilson. the river. Their mode of occurrence is such that they could have been only produced by the river when it flowed at higher levels, and Mr. Wilson is of opinion that a barrier of morainic *débris* must have formed an obstruction across the gorge at this point which has been removed since glacial times, and that the pot-holes show successive stages on the removal of the *débris*. There is also evidence that the upper part of the glen was occupied by a loch which has been drained by the removal of this barrier, and which is now represented in the wider valley above, the bottom of which is filled in with alluvial terraces.

Lismore.—The drift on the Island of Lismore is represented by a Mr. Muff. tough boulder-clay containing scattered stones, many of which must have been derived from the mainland. The matrix of the clay at the north end of the island is somewhat reddish, whilst towards the south-west part of the area it becomes quite black. The change appears to be gradual, and is doubtless due to the grinding up of the limestone and its incorporation in the clay during the south-west movement of the ice. The percentage of limestone boulders in the clay also increases towards the south-west. Amongst the boulders from the mainland the following have been identified by Mr. Peach:—Quartzite, porphyrite (probably of Old Red Sandstone age), Old Red Sandstone arkose (from the Great Glen), many varieties of granite, including some traversed by pegmatite veins, from the north side of the Great Glen, and also the basic edge of the Cruachan mass, Moine schist, and an agglomerate like that of Ben Nevis. The boulder-clay forms a few mounds situated on the lower ground or banked against steep limestone scarps. Two winding kames, situated half-a-mile south-west of Port Ramsay, run across the low ground in a south-east direction.

Large boulders of granite and quartzite are scattered over the hills at all altitudes. Some lie against a pedestal of limestone, which they doubtless formerly capped.

The direction taken by the striae is very variable, but is, on the whole, about parallel to the long axis of the island, and the striae indicate a south-westerly movement of the ice. On a small island west of Eilean Ramsay a set of striae, running from N. 5° E., is crossed by a later set running from N. 70° E. The striae are preserved only on the igneous rocks, and then almost always between tide marks. Some idea of the rate of the atmospheric denudation of the limestones may be gained from the fact that at low water mark the limestone is nearly flush with the striated surface of a dyke, whilst at about high water mark the striated surface on the dyke stands about one foot above the surface of the limestone. This denudation must have taken place, if not since the epoch of the 25-feet beach, at any rate since that of the 50-feet beach.

Region south of Oban.—In the area near Kilmore, mapped Mr. Peach. by Mr. Peach during the season, the glacial phenomena are almost entirely attributable to the later glaciation. The striae show a general ice movement across the country from E. to W. On the high plateau between Loch Nell and the Feochan Beg,

Mr. Peach.

the striæ trend a little to the north of west, while those found in the valleys have a tendency more or less to conform to the direction of the valleys. Moraines made up in great part of schistose rocks, and granite from the Cruachan region are scattered over the plateau independently of the present valley system in such a manner as to show that the glaciers after leaving the Highlands must have coalesced and over-ridden this part of the surrounding lower ground. Loch Nell seems to have been the site of a tongue of this ice during the 100-feet beach time, as moraines are found on the terrace of the 100-feet beach which forms its present dam. Another tongue of the ice must have occupied the Feochan Beg as far down as Craigentaggart during, or since the 100-feet beach time, as moraines are found in the bottom of the valley above, which at this point is below the 100-feet level, while further down the river has cut its terraces of alluvium through the 100-feet and 50-feet beaches.

Trains of boulders are common across the area in the same general direction as the striæ. Thus north of Loch Nell there is a wide train of boulder of Cruachan granite; but perhaps one of the most striking trains of boulders is that supplied by an exposed portion of a large porphyrite dyke occurring on the hill top to the south of Glenamacrie, in Glen Lonan, from which a very conspicuous train of boulders can be traced to Torran Tuire, near the head of Loch Nell.

Messrs.
Peach,
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Muff.

Kilmartin District of Argyllshire.—In the narrow belt of ground mapped in this region during the season, stretching from Loch Avich in the north to the Crinan Sea Loch on the south, the rock is singularly bare of drift. The ice-movement over the area, as indicated by the striæ and the carry of blocks, was towards the W.S.W., with local deviations according to the shape of the ground.

The sparse glacial deposits are mostly of a morainic character, but Mr. Muff mapped some small areas in the neighbourhood of Salachary of what may be looked on as Boulder Clay. With perhaps this exception, most of the phenomena observed are attributable to the Later Glaciation, when the glaciers from the higher Highland valleys to the head of Loch Awe coalesced on the low ground and overrid the lower plateau of which the present is a portion. Moraines are common to the south of Loch Avich, on the water-shed between Glen Domhainn and Loch Awe, where they could not be laid down by local glaciers nursed within the water-shed. Boulders, foreign to the region, such as granite and schist, like those surrounding the Cruachan massif, are scattered over the area. Boulders of andesite and porphyrite like those which traverse the andesite rocks north of Loch Awe are abundant within the area.

As probably showing a stage in the shrinking of this confluent glacier, a lake terrace 200 feet above the present level of the loch is found round the S.W. or upper end of Loch Avich, of such a character and in such a position that it must have been formed when the lake drained to the S.W. into Glen Domhainn, the head of the Barbreck River. The gravels and sands of this

terrace have been traced to the actual water-shed at about one-third of a mile to the S.W. of Maolachy on the road between Kilmelfort and Loch Avich, where the road traverses a small rocky gorge evidently cut by the water flowing out of the lake. The fine silts and sands of the terrace can also be seen near the roadside near the same spot. The present outlet of the lake shows no evidence of a barrier of moraine stuff or rock of such depth having been removed since glacial times, and the only explanation of the high terrace, which is in every way comparable to one of the terraces of the "Parallel Roads of Glen Roy," is that the barrier was due to the lower end of the lake being occupied by ice when the terrace was formed.

Messrs.
Peach,
Wilson and
Muff.

Island of Soay.—As might be expected from the exposed position of the Island of Soay, the material in the raised beaches is very coarse. To a large extent it is composed of boulders two or three feet long, which have been piled up in storm banks. There are small deposits of gravel as much as 60 feet high, but perhaps these were thrown up in storms considerably above the general sea-level.

Mr. Clough.

Lismore.—The north coast of Lismore bears a well marked terrace at an altitude of about 35 feet above O.D., which doubtless corresponds to the 50-foot beach of neighbouring areas. Though usually a bare rock ledge, it is sometimes covered by water-worn gravel, containing similar rocks to those found in the Boulder Clay, in addition to many limestone pebbles. No shells have been obtained from this deposit. Undisturbed Boulder Clay reaches down to this beach, and no evidence of a higher beach was obtained. The cliffs bounding the 50-foot beach are indented by many small caves, whose walls are covered by stalactites. At Sron-na-bravibhe, in place of the cliffs there is found a curved ridge of gravel, concave towards the sea, and formed of false bedded ferruginous sand and gravel of essentially the same composition as that found on the 50-foot beach elsewhere. This ridge in cross section has a long gentle slope seawards, and a short steep slope on the landward side, where the surface drainage is obstructed and a peat moss has formed. Similar though smaller ridges, are found in analogous positions to the north and to the south of Port Ramsay. They appear to be storm beaches of the 50-foot beach period, behind which shallow lagoons may have existed at that epoch.

Mr. Muff.

A lower raised beach, which is distinguished only with difficulty from a more modern storm beach, appears to be preserved only near Port Ramsay, where the coast is sheltered by small islands. Peat, besides filling shallow depressions of the Boulder Clay surface and lying behind the old storm beaches already described, occupies the site of former lochs, at the source of Allt a'Mhuilinn and again just south of the school house.

Lorne District.—Near Kilmore the 100-foot raised beach occupies a well-marked terrace at the foot of Loch Nell and in the angle between the Feochan Mor and Feochan Beg rivers. The terrace, partly as a rock notch and partly covered with beach

Mr. Peach.

Mr. Peach. materials, can be traced down the south-east side of Loch Feochan for some distance from its head.

The 50-feet beach is also well displayed in the same district. At Kilmore it is much covered by a coating of peat. It can be easily followed down the south-east coast of Loch Feochan close to the high road, and the rock caves along its margin are still often tenanted by tinkers and tramps who contribute the refuse of the shellfish they use as food to the kitchen middens found at their mouths.

Mr. Wilson. *Kilmartin District.*—The 50 feet beach is well marked along the seaboard from Crinan Loch to the head of Loch Craignish and also to Island Macaskan and Eilean Rìgh. It extends up the Kilmartin Valley to within a mile of the village, and on it rests the extensive peat-mosses of Moine Mhor and Poltalloch. This terrace is generally composed of rolled stones and gravel, and a section on the River Add, near Drumore, shows ten feet of fine horizontally-bedded gravel on top of stiff, light grey Boulder Clay.

On the east side of Loch Craignish and the two islands, the 100-feet beach is not well marked, but in the Kilmartin valley on both sides it forms a conspicuous feature, and extends as far up as the cross roads to Ford and Oban. A short distance to the west of Eurach a belt of epidiorite lies just beyond the upper limit of this beach and extends across the valley. This band has numerous pot holes, which must have been formed during the 100-feet beach period, and when the surplus water of Loch Awe passed down the Eurach valley. At Slockavullin and near Balameanoch, clay pits have been wrought in this beach deposit and a fair quality of bricks and tiles produced.

Messrs. Muff, Peach, and Wilson. *Economic Minerals.*—The largest area of limestone is to be found in Lismore. At present it is only burnt at Port Ramsay, whence it is taken away in boats, and there is an annual output of about 600 tons; but the supply is practically inexhaustible. Limestone has been more or less locally wrought and burnt all over the Kilmartin area, but at present it is evidently cheaper to import lime from Lismore and other places than to produce it on the spot.

The epidiorite sills afford the best building stone in the Kilmartin region. Any granite used in this part of the country is obtained from boulders. The limestone and quartzite are used considerably for drystone dyke building.

Road metal is everywhere easily procurable and of excellent quality, owing to the innumerable basalt and dolerite dykes that traverse the region. The little dark limestone that is found in the black schist, especially where it has been slightly altered, near one of the basalt dykes, also affords good road metal.

A brick clay was formerly used at Slockavullin, one mile south-east of Kilmartin. It appears to have originated from the alluvium of the Slockavullin stream, where it has been dammed back by a spit of the 100-feet beach. The clay appears to be exhausted or no longer workable.

In this district the Moine Mhor and Poltalloch peat mosses Mr. Wilson. afford an almost inexhaustible supply of fuel. Some years ago Lord Malcolm of Poltalloch erected plant for converting the raw peat into peat coke. The machinery came from Sweden and the experiment was highly successful, but on account of the small size of the plant the financial results were not satisfactory. This year the machinery has been removed to the south side of the Moine Mhor, and, with additions, it is to be employed on a much larger scale in the production of coke for the iron smelting works which are being built near Island Add Bridge.

More than a hundred years ago several small veins of copper were wrought at the top of the hill, and close to the old hill road which crosses from Kilmartin House to old Poltalloch. The veins intersect the large epidiorite sill, and these have been only opened up by shallow trenches and a small water level, about twenty yards long, with connecting shaft of similar length, to the hill face above. The ore obtained was chiefly malachite with a little black oxide of copper and manganese. The leading vein is about four feet in breadth and the walls are lined with calcite and quartz crystals. The vein face at the end of the water level is cemented up with stalactitic material and quite concealed.

3.—EAST HIGHLAND DISTRICT.

Dr. J. Horne, F.R.S., District-Geologist (acting).	
Mr. G. Barrow,	
Mr. E. H. Cunningham-Craig,	} Geologists.
Mr. J. S. G. Wilson,	

In the Eastern Highlands, Mr. Barrow continued field-work in the district of the Tarf Valley, in Atholl Forest, in Sheet 64 one inch; and Mr. Cunningham Craig surveyed a tract lying immediately to the north in the Glen Feshie Forest and in the neighbourhood of Newtonmore. In the autumn Mr. Barrow completed the mapping of a small unfinished area near Balmoral in Sheet 65 one inch. In connection with the publication of Sheet 55 one inch, Mr. Barrow re-examined the Garry section north of Blair Atholl; Mr. Wilson drew additional boundary lines in Strath Tummel; and Mr. Craig mapped in great detail the area extending from a line north of Pitlochry to near Blair Atholl.

Tarf District.—Mr. Barrow reports that a considerable portion Mr. Barrow. of the area drained by the Tarf, on the north side of the Tilt valley, in Sheet 64, is composed of typical Moine-gneisses which, on the whole, closely resemble the gneisses of the Bynach area, described in a previous report. The tendency to local variations in the gneisses of the latter, has also been observed in the Tarf area. There are, however, some differences between the rocks of the two areas. The colour banding so common near the Bynach is not so frequently met with in the area surveyed during the past season.

Mr. Barrow. The typical parallel structure is present over most of the area, but it is often shown more by the parallelism of the biotite than by any other feature. This local peculiarity of the gneisses is clearly connected with another which characterises parts of this district. The Moine gneisses often weather like a fine-grained granite—a feature which is not confined to a few small bands; indeed large masses of rock at a short distance off so closely resemble granite in appearance that the rocks had to be carefully examined to make sure that they were not really original igneous material intruded in a sill-like form in the Moine gneisses. It was found that in this type of rock a vast number of small patches had lost all trace of parallel structure; indeed the transition to the part of the rock showing the normal parallel arrangement of the biotite is so gradual, that a series of specimens has been collected to investigate the structure and composition of this type of material.

While over much of the district the arrangement of micas and the colour banding, when well marked, is parallel to the original bedding of the rocks from which these gneisses have been formed, there is rather a broad belt in which this is not the case. In this belt the gneisses show the typical thrust-plane structure of the Southern Highland grits. These thrust-planes cut the rocks intersected by them into thin phacoids in which the relation of the main axis of deformation to that of the least is largely determined by the fineness or coarseness of grain of the sandstone or grit before deformation. A grit is cut into much shorter and thicker lenticles than a fine green sandstone or greywacke; and from the tenuity of the phacoids in these Moine gneisses we at once know that they were originally very fine grained rocks, containing a considerable amount of chloritic material. The cause of this deformation has been well established. It is connected with the trend of the dyke-like intrusions that supplies the material of the sills of epidiorite in the Southern Highlands.

While the bulk of the Moine gneisses must have been originally very fine sandstones, here and there this material was replaced by what was originally more of the nature of a shale. Though now altered to an oligoclase-biotite gneiss, there is no doubt that it was originally a shale, for it still retains the minute puckering which is distinctive of altered shales as opposed to sandstones, which never show this feature except at their junction with a softer rock.

A special feature of the Tarf area is the frequency with which the junction of the gneisses with the Central Highland quartzite can be observed, and as a rule there is a very gradual passage from one rock to the other. Still more important, however, is the clear evidence that the whole of the Moine gneisses in the region examined by Mr. Barrow lie between the quartzite on the one hand and the Little Limestone (Tremolite limestone of Braemar) on the other. They are, in fact, only a small zone in the Highland rocks.

The details of the evidence in the Tarf area are complicated by the interruptions due to the great intrusions of Newer Granite in the district, but there can be no doubt that these gneisses do lie between the two rocks named above.

This conclusion is further strengthened by the evidence in the Falar area, which may here be described.

In Glen Mhor, a little below the junction with Glen Bheag, a remarkable group of rocks is seen which have been called "hone-stones," as they were for many years used as hones, and people came to this locality from great distances to get them. Similar rocks are known to occur at this horizon in many localities. They are clearly seen to lie between the quartzite and the Little Limestone (Tremolite limestone of Braemar). The dominant constituent of the group is a thin banded fine-grained brownish rock, essentially composed of a granular admixture of quartz and felspar, through which a considerable amount of brown mica is disseminated. The mica occurs parallel to the banding of the rocks and intensifies the evenly bedded aspect of these "hone-stones." The brown bands are often separated by thin partings of more micaceous material, clearly mud or shale originally, which was "cross-cleaved" prior to crystallisation: a phenomenon identical with that seen in the Silurian rocks of the north of England. The occurrence of these "cross-cleaved" bands, persistently parallel to the brown bands, is clear proof of original bedding in these crystalline rocks. In addition to these constituents, there are also a few thin bands of pink weathering granular material, and more rarely a few white layers. The composition of the latter is of importance; for while there is hardly any white mica in the brown bands, there is usually a considerable amount in the pink and white material. There is still another distinctive feature of the group. The brown beds are divided up into thin layers by extremely persistent films of what was originally chlorite, but is now more or less completely altered to a "felt" of brown mica. Thus it will be seen that these beds are a singularly well-marked group in which parallel banding is the dominant feature, and if we start from the edge of the quartzite we see at once that they are essentially a passage material between the quartzite and the dark shales, on the reverse side of the Little Limestone. These rocks, when traced, frequently undergo local changes in composition, becoming more or less siliceous, but each individual band of the whole group undergoes this change; no band is cut out and replaced by material of different composition.

In the bed of the Tilt, just below Pool Tarf, the "honestone phase" of these rocks is exceptionally well seen; but here they are slightly thicker as a whole, and this slight thickening is well shown by the cross-cleaved bands. At this point they occur exactly on the line of rapidly increasing alteration, to which attention has been drawn in former reports and which will be referred to again in the sequel. From this locality the rocks become rapidly more crystalline, and this change can be followed on bare rock onwards to Pool Tarf, and up the gorge of the Tarf,

Mr. Barrow. where they rapidly pass into the typical Moine-gneiss of the great area to the north. It is fortunate that these beds can be so quickly traced from the less altered to the far more highly crystalline condition without the intervention of any infold of other material to break the continuity of the evidence.

Bynack District.—Confirmatory evidence is obtained in the Bynack area, where the Moine gneisses have an almost identical structure and composition with that of the "honestones." The typical grey gneiss, by far the most important member of the group, contains little and often no white mica, while the pink and white bands invariably do so, as in the "honestones." The structure is essentially granular in both rocks, but the grains are much smaller in the "honestones." The biotite in both rocks has essentially the same colour, being intermediate between that of Haughtonite and the rich red contact mica.

Struan District.—The widening of the Highland Railway above Struan has exposed admirable sections of the Moine gneisses. As usual they show the parallel banding due to layers of different composition, as well as the parallel arrangement of the micas. The dominant constituent of the group is the grey well crystallised gneiss, which is associated with a subordinate amount of pink and white gneiss. In addition cross-cleaved mica gneisses are present, but these form quite a small proportion of the whole. The increased thickness of the latter when compared with the "honestones" is even more marked than in the Tarf area. The examination of the whole series of sections suggests that there is only one moderately thick bed of cross-cleaved mica gneiss, for wherever visible it is apparently always accompanied by the same grey, pink, and white bands, though there is often a certain disparity in the relative thickness of these three components. The railway sections show that though there is a steady dip in one direction, the same beds are constantly repeated. It is here seen that at short intervals the rise of the beds, owing to the persistent dip, is counteracted by a short, nearly vertical, roll over. This roll over can be made out in the river sections, but its effect in individual cases can rarely be traced with the clearness made possible by these new railway cuttings. These rocks in Glengarry have long been known as the Struan Flags from their flaggy mode of weathering—a feature which is largely due to the original presence of felted chlorite (now biotite) films, as in the "honestones." These films are often a specially marked feature of the Struan or Garry gneisses. As usual there is a considerable amount of variation in the composition of these rocks, but, broadly speaking, it is much less pronounced than in the area farther east. It may be noted that before crystallisation, the original beds in this district underwent far more mechanical deformation than in the Bynack and other areas, which has resulted in the production of a greater amount of white mica.

The further examination of the deep sections in the Falar area **Mr. Barrow**, by Mr. Barrow has thrown much light on the other members of the succession which are there associated with the parallel banded series or Moine gneisses.

With regard to the succession, whether ascending or descending, it is as follows, *when complete* :—

1. The altered parallel banded calcareous shales.
2. The Main Limestone.
3. The dark or leaden schist.
4. The Little Limestone (locally the Tremolite limestone).
5. The parallel banded series (honestones, etc.).
6. The Central Highland quartzite.

(1) The altered parallel banded calcareous shales are among the most easily identified rocks in the Highlands, and are never absent, to my knowledge, from any valley between two quartzite mountains broad enough to show the whole succession. They occur at intervals from Falar to Braemar, and where some of these bands have a suitable composition they always have a peculiarly hornfelsed character. The thicker and more calcareous bands contain white pyroxene and are far more coarsely crystalline—a feature which is characteristic of the outcrops between Ben Vuroch and Braemar. Nevertheless, within certain limits, these bands vary incessantly in total chemical composition.

(2) *The Main Limestone*.—This can generally be recognised by its purity and persistent thickness. When specially siliceous, as in Glen Mhor, every member of the succession with which it is associated is more than usually siliceous, except of course the quartzite.

(3) The dark or leaden schist, which covers such large areas, varies considerably in composition in different localities. In its normal dark phase this schist may be divided into certain well-defined zones that have been traced over a large area. A little way from the edge of the Main Limestone it contains a large amount of kyanite, in regions of moderately high alteration, but this gives place to other silica aluminates, such as sillimanite, andalusite, or cordierite, in the areas of highest alteration. Nearer the Little Limestone we have the rock with felspar (or hornfels of Glen Callater), and the zone, with large plates of twin-chlorite. In many cases, these schists, originally rich in chlorite, contain a peculiar association of micas; the normal white mica does not occur in them. No part of this schist, in all this area, ever possesses the dead-black colour, accompanied by disseminated graphite that so often characterises part of the true graphite schist.

(4) *The Little Limestone*.—In tracing the changes that occur in this sedimentary series, it has been found that this limestone is altered to a Tremolite-rock only when the schist next it is dark in colour and associated with the twin-chlorite-rock and the felspar-rock. In varying phase of composition it occurs over a very large area. North of the Tilt it is usually an intensely hard, green, flinty rock, containing a very variable amount of garnet, and a smaller quantity of idocrase. The green colour is due to disseminated

Mr. Barrow. green pyroxene. In the Tilt valley it is less highly crystalline, but, being frequently exposed in the river bed, we are able to note how very variable in composition the rock is. It is doubtful if green pyroxene occurs here, but garnet and a little idocrase are sometimes found. In the Glen Mhor area it is usually a rather siliceous limestone, with lenticular siliceous ribs, somewhat resembling those seen at one locality in the Main Limestone. In this phase the Little Limestone occurs in a great number of places, but, previously, it was regarded as the base of the Main Limestone, caught in a fold. On this supposition the structure of the ground was difficult to understand, but the map is at once rendered intelligible when we know that there are two limestones, and not one. About four miles south of Braemar this bed again occurs, where it contains numerous garnets, but no pyroxene. About the north side of the Dee it re-appears as a green, flinty rock where next the parallel banded series. Again, east of Balmoral, the same flinty green rock, with garnet and a little idocrase, is seen, but nearer Badvo the green portion is a mere film, and the main part of the rock is now built up of radiating spherical masses of Tremolite, associated with some calcite and a micaceous mineral. Throughout its whole course it shows liability to change in chemical composition, like the parallel banded series.

(5) The parallel banded series has already been sufficiently described, but the zone shows better than any other the fact that these rocks, while incessantly changing, also incessantly revert to the normal type. Thus the flaggy hornfels of Glen Callater is the flaggy hornfels of Glen Fender, near the mouth of Glen Tilt, and the hard, parallel banded biotite schist next the Little Limestone in Glen Mhor was obviously the same material, originally, as the hard, banded biotite schist to the east of Balmoral.

(6) *The Central Highland Quartzite.*—This zone furnishes remarkable evidence bearing on the original thickness of the Highland series. The succession is as follows:—

- (a) The fine white edge of the quartzite.
- (b) The quartzite banded by fine lines of heavy minerals.
- (c) The porous quartzite.

The porous quartzite, which is between six and eight feet from the fine white edge of the mass, is very easily recognised from the holes left in it owing to the decomposition of rather large and scattered felspar pebbles. (The remnants of these in the holes were clearly seen both by Mr. Horne and myself.) Now this band, according to Mr. Barrow's observations, runs through almost every great quartzite mountain, and the evidence suggests that these three zones together form the greater part of the original mass. Ben y Ghloe is formed of quartzite, folded on itself to the exclusion of every other rock. The folds in this mountain are 2,400 feet deep at least, and there is not a bend or buckle in the folds, while the bedding planes and limbs of the folds have a persistent dip of 60° for nearly two miles. The porous quartzite occurs repeatedly in this mountain, as it does again in another huge mass of quartzite seen in Cairn Righ, farther east. As

already stated, its mode of occurrence is such as to suggest that Mr. Barrow. there is probably not much more than the three bands, a, b, and c, present, and we are led to the conclusion that these enormous masses of quartzite are built up by the isoclinal folding of a bed that may be not more than twenty or thirty feet thick originally.

At intervals, across the whole area known to Mr. Barrow, parts of the series are missing. This is clearly shown when the Main Limestone is in contact with the quartzite. The phenomenon suggests that we are dealing either with non-deposition, due to current action, or with local erosion, equally due to current action. The probability is that in such a series we are dealing with both, and the mode of occurrence of the "Boulder-bed" is strongly suggestive of local erosion.

The further result of the work in this district shows that a line or belt of rapidly increasing alteration can be traced from the upper part of the Dee to a point a little north of Blair Athol. This belt passes through the great mass of basic diorite in Glen Tilt, without being the least affected by that intrusion; and the line can again be shown to be independent of Newer Granite intrusions, as proved in the Bynack area, where the Newer Granite is comparatively rare. From Braemar a similar line roughly corresponding with the Dee can be traced for about four miles down the river. It has been shown by the rock sections that the increase in crystallisation to the N. of this line becomes less and less marked, till in the area east of Balmoral it is very slight and extremely gradual. This progressive metamorphism is intimately connected with the problem of the widespread hornfels type of alteration which will now be described.

The evidence on this interesting question now points clearly to a definite cause for this alteration. This type has been found in the Falar and other areas, where the metamorphism cannot be attributed to Newer Granite alteration. It occurs repeatedly between Ben Vuroch and Braemar; and is mainly confined, when well shown, to two beds. The first of these is the banded calcareous shale next the Main Limestone. In this, as already stated, the bands are almost glassy at times, and the constituent grains are there very small.

The other bed is the Flinty-biotite schist, next the Little Limestone, which occurs repeatedly and has in no case been produced by Newer Granite alteration. The feature of this rock, too, is its fine grain. It clearly consisted originally of an admixture of fine quartz, some felspar, and a considerable amount of chlorite. The fine chlorite acts at a specially low temperature on the quartz, and the rock becomes indurated and, unless the material be afterwards crushed, retains this induration, accompanied by a finely crystalline condition. At times another rock shows this hornfels type of alteration: but in this case it is not so finely crystalline. This is the felspar-hornfels of the Glen Callater type, which occurs twice in the Falar area. A section shows that this is even a better example of hornfels alteration than the Glen Callater rock. It is at least fifteen miles from the Lochnagar granite and a great distance from any Newer Granite intrusion,

Mr. Barrow. while the Glen Callater rock is actually inside the Lochnagar granite. It is thus perfectly clear that the hornfels structure of this rock has nothing to do with the Newer Granite mass of Lochnagar, and that this gneous mass has produced practically no effect on the Highland rocks, the crystallisation of which is obviously pre-granitic.

Turning now to the area east of Balmoral there is no sign of increasing alteration in the Highland rocks as we approach the eastern margin of the Lochnagar complex. The lines of very slow increasing alteration trend east and west at right angles to that margin. With material of similar composition, it is found that these rocks possess a common feature and one that distinguishes them from all others in the Highlands. The true hornfels rocks, when in an area of high or moderately high alteration, are distinguished by the occurrence of a great number of minute flecks of biotite distributed through the rock. (This mineral usually possesses a rich brown colour.) The evidence already obtained makes it practically certain that this flecking is due to the (early) action of the chlorite on the quartz which produced an induration that made it difficult for material to migrate. This dissemination of flecks of biotite never occurs in a thoroughly schistose or gneissose rock.

Newer Igneous Masses.—A considerable mass of Newer Granite has been mapped on the north-west side of the Tilt Valley. Part of this area was formerly surveyed by Mr. Dakyns, and specimens were collected which have been described by Mr. Teall. Briefly, the complex consists of variations of diorite, the greater part of which is distinctly basic, and modifications of granite, the bulk of which is markedly acid and contains much free quartz. But there are some phenomena of extreme interest associated with these intrusions. They are connected with the foliation of certain small intrusions, the occurrence of dyke areas and dyke-free areas, and also with what may be conveniently called the "roof" of the complex. The phenomena associated with the latter are specially interesting in view of the idea they suggest as to the mode of intrusion of the granite. The composition of the material around and above the intrusion (Quartzite and Moine gneisses) is prohibitive of the view of the formation of the granite approximately *in situ*, by absorption of the surrounding material, while the mapping of the "roof" shows that the idea of upheaval of the overlying rocks is equally unlikely. The mode of occurrence of the acid material suggests a new, and possibly in many cases a far more reasonable, explanation of the mode of intrusion of these granite masses. It is seen that acid material is injected between the roof or enclosing wall of the older diorite and the diorite itself. The mode of occurrence of these injections suggests that the acid granite did not lift the roof up, but pushed the older more basic igneous material down in many cases. It seems as if the igneous material had forced its way up one or more ducts till a point was reached where it could no longer remain fluid or plastic enough to flow. It then spread out in the form of sheet, working downwards to a warmer and not upwards into a colder environment.

The portion of the great drainage area of the Tay that lies above Pitlochry varies greatly in character. One feature is common to all the minor valleys that together compose the area. They are locally covered with peat and drift, the latter being a softish clay or gravel. In consequence they all bring down a certain amount of highly micaceous fine mud and peat held in mechanical suspension. Mr. Barrow.

To the N.E. of Pitlochry there are thick masses of limestone; these cause a considerable amount of lime in solution to enter the main drainage valley. A similar limestone area occurs on one side of the Tilt above Blair Athol; this again imparts much lime in solution to the water of the Tilt.

On the N.W. side of the Tilt, particularly in the Tarf Valley, are considerable masses of granite and granite drift. The latter contains a large proportion of decomposing felspar, which gives out a large quantity of soluble silica when rain percolates through this granite drift.* In flood times the water in the Tarf is almost black with peat.

The upper part of the Garry supplies a fair amount of silica, the rocks over which the rainfall passes being mainly felspathic gneisses. There is little lime in this area.

The Tummel drains a large area of granite and quartzose gneisses, much of the ground being covered with peat. It passes through two large lakes, Loch Rannoch and Loch Tummel, and, except in specially heavy floods, the Tummel water is greatly filtered and cleared of impurity in its passage through these lakes.

Glen Feshie District.—In the area surveyed by Mr. Craig in the Glen Feshie district, the rock consists of Moine schists of the siliceous type, with many small intrusions, chiefly granitic. Mr. Craig.

Two types of the schists can be distinguished, but it is not possible to separate them on the field maps. The first consists of flaggy quartz-biotite-gneisses or schists, highly granulitic, and occasionally with fairly thick massive beds; these rocks contain very little muscovite, and that chiefly along planes where differential movement was greatest. The second type is much more highly felspathic and does not weather into flags, muscovite is more abundant, though biotite is still always present. On a cross fracture the beds often appear almost granitic in character.

Newer Igneous Rocks.—Intruded into these schists, small diorites and lamprophyre dykes and sills are seen; they are of the usual type of the newer diorites and lamprophyres of the Braemar district.

Granitic intrusions are frequent, as might be expected, in an area lying between the Cairngorm granite on the N.E., and the Beinn Dearg granite on the south. An extension of the

* A singularly perfect illustration of the quantity of soluble silica washed out of granite drift is afforded by the mass of diatomite on Duniet Moor, Aberdeen. The supply of silica for this material is derived exclusively from the great mounds of granite drift, the rain falling on the mounds percolating them and issuing charged with silica.

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Beinn Dearg (Perthshire) mass crosses the county boundary, and about two square miles of granite have been mapped on the Inverness-shire side, where it forms Meall Tionnail. This Meall Tionnail granite resembles very closely the Cairngorm granite, especially that type seen on Beinn Bhrotain, *i.e.*, very acid, with very little biotite, and fairly coarse in grain. Indeed at one part of the margin the Meall Tionnail granite is practically a binary granite, very coarse, and with a few large scattered flakes of biotite. It is coarse right up to the margin. This mass is also characterised by the absence of the much more acid intrusions which are so common in many parts of the Cairngorm mass, and by the fact that it does not seem to be affected by fault movements. From these data it appears probable that the Meall Tionnail granite represents one of the latest phases of the Cairngorm granite intrusions.

Apart from the large mass of granite forming Meall Tionnail, there are no acid intrusions of any great extent; though veins are very numerous, they never attain large dimensions. These veins vary in character considerably, aplites, fine and coarse granites, and pegmatites are frequent all over the area except in the N.W. part, where one passes gradually from an area characterised by the intrusion of plutonic rock of the Newer Granite to an area in which the intrusions have been cooled more quickly, and appear as quartz-porphyrics and felstones with chilled edges. One well-marked sill has been mapped, its eastern extremity being granite, and its extension to the N. and W. being quartz-porphyry. In the intermediate area specimens ranging between granite and quartz-porphyry can be obtained; a phenomenon observed near Braemar, where the Auchindryne granite passes westward into quartz-porphyry.

The granite veins frequently exhibit coarse central zones of pegmatitic material, and sometimes have coarse pegmatite margins also, thus resembling the later vein intrusions in the granite mass of the Cairngorms.

A small part of the margin of the Cairngorm granite, east of the river Eidart was examined. It presented no remarkable characteristics, but the metamorphic rocks within half a mile of the junction are pierced by a great number of granite veins, coarse red pegmatites and pale aplites, all of which are of the Newer Granite type. There are no foliated muscovite pegmatites of the Chest of Dee type in this locality.

Newtonmore District.—In the area surveyed from Newtonmore, the rocks encountered are the same types of Moine schists, with minute infolds of muscovite-biotite schist in the western part of the area. The development of pegmatite veins in this area presents some points of interest. These veins vary in breadth, from an inch or two up to six feet or more. They are usually along the bedding planes, but sometimes cross them at high angles. No single vein can be traced far. In composition they are usually coarse muscovite pegmatites never showing any signs of being more quickly cooled at the margins; the crystallisation is uniform throughout. These veins never show signs of having been affected

by dynamic metamorphism, and no contact metamorphism has Mr. Craig taken place at their margins, but the country rock appears to have crystallised simultaneously with the pegmatite, the crystals interlocking in the most intimate manner.

When these pegmatites are intruded through rocks rich in biotite, the pegmatites contain a considerable quantity of biotite also, even to the exclusion of muscovite in thin veins, but the usual type in a quartzo-felspathic country rock, not containing much biotite, is a muscovite pegmatite without biotite.

From these facts it appears probable that segregation has taken some part in the formation of these veins, and that they are contemporaneous with the regional metamorphism of the district.

In the area surveyed in Glen Feshie, there is very little soil derived from the disintegration of rock *in situ*. The higher parts of the hills are covered with a stony rubble of the Moine schists, while the area occupied by the Meall Tionnail granite presents a surface of weathered granite blocks and sand.

The lower parts of the glen are entirely covered with sandy morainic *débris*. The greater part of the area is covered with peat which occasionally attains a depth of ten feet.

No part of the ground is cultivated, there are no quarries, and no population, as there are no inhabited houses in the area.

The water supply is abundant, but liable to be somewhat peaty during floods.

The area is part of the Glen Feshie deer forest, and the high ground and alluvial stretches along the river Feshie furnish the rough pasture most favourable to deer. A considerable number of grouse breed on the lower ground, but are not shot in this part of the forest.

To the area surveyed from Newtonmore the same remarks apply, but there are one or two houses with small patches of cultivated ground on the alluvial soil and fluvio-glacial gravels along the river Truim.

The land affords grazing for a few sheep, but its chief value is as a grouse moor, the low lying heather-covered areas affording excellent cover and feeding for the birds.

Aberfeldy District.—The mapping of the Green Bed outcrops south of the Tay, in Sheet 55, has been completed by Mr. Craig, and has, as usual, thrown considerable light upon the structure in this district. The presence of several important faults not previously recognised has been demonstrated, and additional evidence has been obtained regarding the flat-lying type of folding.

The progressive metamorphism northward, to which attention was called in last year's report, can now be considered in greater detail, microscopic examination of a series of specimens chiefly from the Green Beds having been made. A series of specimens taken, roughly speaking, from south to north, exhibits the increase in metamorphism strikingly. Pebbles are very conspicuous in the more southerly outcrops, while garnets are absent, the rocks consisting of biotite-hornblende schists with pebbles of quartz more or less numerous, and a certain amount of granulitic quartz and felspar in the matrix. The quartz pebbles, as pointed

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out by Dr. Flett, consist of lenticles more or less granulitized and showing all stages in the breaking down into a granular mosaic. The felspar Dr. Flett finds to be secondary, and from its low refractive index, as ascertained by Becke's method, must be either albite or orthoclase.

In specimens from outcrops farther to the north, and especially in beds of originally finer material, on which the dynamo-metamorphism has taken greater effect, a further stage in the thermometamorphism is seen. The hornblende still appears in feathery ill-defined prisms, but attacking the quartz pebbles and the granulitic quartz of the matrix. Garnets, small and idiomorphic, are common, while epidote and iron ores are also present.

A gap of from one and a half to two miles separates the outcrop of the Green Beds south of the Tay from that north of the Tay. Two specimens from the outcrop north of the Tay have been microscopically examined. These show such an advanced stage of metamorphism, that they can hardly be distinguished in a microscopic slide from the fine edges of epidiorite sills. No traces of clastic structures are present, and the rocks consist chiefly of hornblende with a few garnets, some quartz and felspar, sometimes biotite, and accessories such as rutile and apatite.

It is noticeable that the garnets usually act as "eyes" in the epidiorite sills, the hornblende of the matrix curving round them, and often leaving triangular patches of quartz or felspar at either end. In the Green Beds, the garnets do not seem to have acted in this manner as a rule, the hornblende crystals abutting against or enclosing them. The foliation of these green beds also seems to be rather more regular than that of the edges of epidiorite sills.

In hand specimens several methods of distinction are possible: the epidiorites have the rusty weathered crust characteristic of igneous rocks; the fracture also resembles that of an igneous rock, and the lustre on a fresh cross fracture is greater than in the case of the Green Beds. In those specimens of Green Beds which most closely resemble the epidiorite sills, the fracture is more earthy, and the weathering and jointing are those of a schist of sedimentary origin; the lustre upon a fresh cross fracture is not so great, and the colour of the hornblende on a cross fracture is lighter, being more distinctly green as compared with the almost black colour of the hornblende in the epidiorites. These characteristics are, as a rule, sufficient to distinguish the edges of epidiorite sills from much altered hornblendic Green Beds, where field evidence is not available.

Specimens from other horizons have been selected and examined microscopically for the purpose of elucidating the progressive metamorphism, but space does not permit of any description of them being given here.

District between Pitlochry and Blair Atholl.—Mr. Craig thus summarises the results of his revision and re-survey of about fifteen square miles of the ground between Pitlochry and Blair Atholl in October, November, and part of December. It was

anticipated that important evidence regarding the succession of Mr. Craig. strata would be obtained in this district, and special attention was accordingly given to evidence bearing in any way upon that question.

The area revised comprises the rocks from a horizon not far to the north of the Loch Tay limestone outcrop, a sill of epidiorite marking the boundary, and so north-westward, northward, and north-eastward to the first main outcrop of Blair Atholl limestone. Geographically, the various members of the series are arranged as follows, the section in the Tummel and Garry Rivers being taken as typical:—

- (5) Blair Atholl Limestone.
- (4) Black Schist.
- (3) Quartzite.
- (2) So-called Graphite Schist.
- (1) So-called Calc Sericite Schist.

(1) The zone to which the name of calc-sericite schist has frequently been given, consists of felted mica schists and phyllites, often with quartz veinlets, but becoming more calcareous near the top, where thin limestones are observed, and calcareous sericitic beds, which have frequently developed bladed crystals of actinolite. These schists and limestone beds will be described in the explanation of Sheet 55 as the Beinn Lawers schists. A very easily recognised thin brownish limestone or dolomite forms the top of this group.

(2) This group consists of a dark leaden-coloured schist, to which the name Graphite Schist has frequently been given, because some of the upper beds are occasionally markedly graphitic. A thin black impure limestone has been mapped near the top of this group.

(3) The Quartzite has been spoken of as the Banffshire, Schiehallien or Central Highland Quartzite. The margin is fine, but a pebbly band is frequently seen a few feet within the mass.

(4) North of the quartzite comes an outcrop of dark leaden-coloured schist which is associated with a mass of (5) Blair Atholl limestone. Repetitions of the quartzite, dark leaden-coloured schist and limestone occupy the surface in the area to the northward. Details, most of which have come to light in the re-survey, are omitted in the above. Associated with limestone, a greater or less thickness of variable schists are sometimes observed, and Phyllitic schists, homotaxial with the black schist, appear in the northern part of the area.

That the series is an upward succession from the Loch Tay limestone to the most southerly outcrop of quartzite has been recognised for many years.

The evidence regarding the succession obtained during the re-survey can be considered conveniently under three heads: (a) Structural evidence, which can be considered irrespective of folding, dip, or pitch; (b) Petrological evidence; (c) Evidence from observation of pitch, and discordant junction of different members of the series.

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(a) The first point of importance is the identification of the dark schist south of the main quartzite outcrop, with that north of the outcrop, *i.e.* (2) is the same as (4). On Meall Uaine, the so-called Graphite schist can be traced round the folds of the base of the quartzite into the black schist to the northward, associated with the Blair Atholl Limestone. There is no drift obscuring the ground, and the section is remarkably clear. The basal edge of the quartzite is seen folded with the under-lying schist, and usually much drawn out by shearing at the actual margin; but a few inches farther in, the quartzite is fairly solid.

Minor zones in the black schist can also be identified on both sides of the outcrop of quartzite. The thin dark limestone already alluded to is seen in several localities south of the quartzite outcrop, and near the summit of Meall Uaine it is found more highly altered, and beginning to develop Tremolite crystals. North of the quartzite it has the same appearance, but as we proceed north-eastward into a region of greater metamorphism, the Tremolite becomes more conspicuous and more highly crystalline, till the rock presents the appearance of the well-known Tremolite limestone, which has been so often recorded as a zone in the black schist, associated with the Blair Atholl limestone.

This identification of the black schist with the so-called Graphite schist, is further confirmed by the mapping of the Ben Lawers Schist, with its characteristic thin limestone band, round from south to north of the outcrop of the quartzite.

This evidence is sufficient to establish the fact that the quartzite is the highest member of the series, lies above the black schist, and when it comes in contact with the Blair Atholl limestone, as near the head of Allt a' Mhagain, must be above that deposit also.

All the rest of the evidence, while amply confirming this conclusion, bears more directly upon the relation of the quartzite to the other rocks in the district. The first point of importance is that no exposure of the Blair Atholl limestone has been observed south of the main outcrop of the quartzite. Again, the margin of the quartzite, and it follows from the evidence stated above that only one margin of the quartzite is seen in this district, comes in contact with the Blair Atholl limestone, variegated schists sometimes associated with the Blair Atholl limestone, the black schist, the Tremolite limestone in the black schist, and the Ben Lawers schist, with its thin band of limestone. It may also be mentioned here that the Quartzite comes in contact with a large laccolitic sill of foliated hornblende rock intruded between the Ben Lawers schist and the black schist, and also with a thin sill of garnetiferous hornblende schist intruded in the black schist. In the third place, the margin of the quartzite is seen to transgress the outcrops of other members of the series, as is indeed necessary in order for it to come in contact with all the above-mentioned groups. This transgression can be seen clearly in ground free from drift.

From these facts it is possible to deduce two alternative explanations: (1) that most of the upper groups die out sporadically to enable the quartzite to apparently descend in the series, or (2) that there is presumptive evidence of an unconformable overlap of the quartzite upon the lower members of the series.

(b) Petrological evidence can be considered next, to see whether it confirms either of the above hypotheses.

A very striking fact came to light during the examination of the basal beds of the quartzite in different localities, *i.e.*, that these basal beds vary in character and composition according to the nature of the underlying rock. Coarse pebbly beds are not infrequent near the base of the quartzite, but the actual margins are almost invariably fine in grain, and appear to contain material derived from the adjacent rock. That this intermingling of material has not been caused by the disruption of bedding planes under shearing forces and the subsequent rearrangement of the affected material, is proved by the perfect continuity of the bedding planes, and the fact that the intermingling of material extends farther into the quartzite than any marginal belt of special shearing due to the sudden change in coefficient of elasticity in passing from a shale to a quartzite. The only possible explanation of the phenomenon is that contemporaneous erosion accompanied the deposition of the basal layers of the quartzite. The thickness of these bands in which evidence of this contemporaneous erosion can be obtained seldom exceeds two feet; they sometimes contain pebbles of quartz and felspar very little affected by shearing. The gradual passage of these bands into the purer quartzite is regular and well marked. Where the quartzite comes in contact with the black schist the basal laminae of the former rock consist of rusty impure sandy micaceous schist containing muscovite, biotite, graphite (?) in some places, iron ores, and occasionally needles of tourmaline. These beds are usually soft and rusty, and are separated by films of sandy micaceous schist of a type differing completely from the normal black schist. This marginal type of the quartzite has been described in other areas as the Coire Neid type. When the quartzite comes in contact with the Tremolite limestone band in the black schist, the basal beds consist of impure calcareous quartzite, which is usually very rotten and friable, owing to the lime dissolving out under weathering processes and leaving the silica. There is not a sufficient area of contact between the quartzite and the Blair Atholl limestone in this district to make it possible to describe the general type of the marginal beds of the quartzite under these circumstances, but where the quartzite comes in contact with the variegated schists associated with the Blair Atholl limestone, and with the garnetiferous hornblende schist still in the black schist, the basal beds are represented by a very variable series of schists composed of quartz, felspar, muscovite, biotite, garnets, and occasionally hornblende or calcite, each constituent varying in quantity in different bands or different localities, but the whole, by becoming more quartzose, gradually passing into pure quartzite.

Mr. Craig.

Throughout a great part of the area where there are no large outcrops of quartzite small infolds of the base of the quartzite are frequent. These infolds are sometimes very minute, but are invariably recognisable, and present the same phenomena of contemporaneous erosion and deposit.

Thus it has been seen that the base of the quartzite not only transgresses the boundaries between other members of the series but that its deposition was accompanied by local erosion in this area, and it follows that the quartzite is not conformable to the other members of the series. How great the unconformability may be it is impossible to say from the evidence in this district, but the absence of the Blair Atholl limestone from the area south of the first main outcrop of the quartzite is very significant; the limestone may either have never been deposited or it may have been entirely removed by denudation.

(c) Observations of the pitch of the folding confirm what is stated above with regard to the order of succession; Ben Lawers schist, black schist, Tremolite limestone, variegated schists, and Blair Atholl limestone are all seen to pitch below the quartzite.

The actual discordance between the bedding of quartzite and black schist can be seen in several places both south and north of the main quartzite outcrop, where the bases of folds of that rock are seen in contact with the black schist. Hand specimens can even be obtained showing this discordance, which may appear only as current bedding, but may mark a very considerable unconformity.

The succession, then, in this district, is proved to be as follows, in descending order:—

4. Quartzite.
3. Blair Atholl Limestone.
2. Black Schist, with Tremolite limestone near the top.
1. Ben Lawers Schists, with thin limestone at the top.

A gentle unconformability, which may be only local or may be of considerable magnitude, occurs at the base of 4, and occasionally cutting out 2 and 3 completely.

A point of great interest in the district is the development of pre-folding basic intrusions. Mr. Barrow pointed out several years ago that the source of at least one of the hornblende schist sills can be seen on Beinn Vrackie. It takes the form of a large flattened laccolite, spreading out into a thick sill, which thins out rapidly to the south and west, while to the north and east it extends farther. It is possible that there is more than one intrusion, but as the ground has not been entirely surveyed, it is impossible to be certain on this point. The main laccolite, which causes the strike of the strata to be deflected round it in a most regular manner, is intruded between the Ben Lawers schist and the black schist, approximately, but it also gives off a minor sill, which occupies a low horizon in the black schist. The igneous mass has been thrown into large rolling folds, while the surrounding rocks, of sedimentary origin, were compressed into

a vertical isocline. The edges of the main sill, however, and the minor sill, have shared in the intense folding of the sedimentary series. Mr. Craig.

No detailed examination of the petrological characters of these intrusions has yet been made. It will be sufficient to state that the main intrusion, where it is least affected by movement, is a holocrystalline hornblende rock, very basic in composition, while the margins are represented by finely laminated hornblende schists, nearly always containing some garnets.

The sill in the black schist is invariably a very garnetiferous hornblende schist, the garnets sometimes attaining a diameter of an inch or more, while biotite is frequently present.

The main laccolite has caused considerable alteration of the hornfels type in the black schist, the latter rock being intensely indurated, so much so that, for a distance of from five to twenty yards from the junction, the hornfels has been able to resist, to a great extent, the shearing forces consequent upon the folding, so that it exists now as a compact hornfels.

It is in the relations of the quartzite to these basic intrusions that one of the most interesting problems of this district is found.

At Aldelune, throughout the Pass of Killiecrankie as far as a point just above the junction of the Garry and Tummel, and for several square miles to the east and north-east, the base of the Quartzite is continually coming in contact with the garnetiferous hornblende schist sill in the black schist. This sill is folded again and again with the base of the quartzite, but in no instance has it been seen to intrude in the quartzite. Following the lower edge of the latter, the sill is sometimes seen to be separated by a few feet of black schist from the arenaceous rock, sometimes a thickness of from a few inches up to six or eight feet of the sill is seen in actual contact with the base of the arenaceous group, while sometimes the sill appears to be absent altogether. Where the base of the quartzite descends in the series to the horizon of the Ben Lawers schist, no trace of this sill is seen.

Where this minor sill is in actual contact with the quartzite, a remarkable variation in the composition of the latter rock is noticed. The lowest layers for a thickness of from a few inches up to about three feet are not quartzite, but consist of highly quartzose rocks of variable composition containing biotite, some white mica, garnets, and very frequently hornblende. In these rocks the bedding is well marked, and on fresh fracture they present the appearance of banded, bluish, rusty-weathering quartzose schists, with the fracture and typical weathering of quartzite. In the Pass of Killiecrankie excellent waterworn sections of these marginal rocks are seen, biotite being the most abundant ferromagnesian mineral. Where hornblende occurs it is usually in bladed or feathery crystals lying at all angles to the bedding; garnet is always present in such cases, while biotite is less abundant, and white mica is more conspicuous.

The various bands differ in composition by the increase or decrease of one or more of the constituent minerals, but all varieties, by becoming gradually more quartzose to the exclusion

Mr. Craig

of impurities, pass into the solid quartzite. Sometimes an almost pure quartzite with a few garnets is observed. The pebbles, which not infrequently characterise the lower beds of the quartzite, have occasionally been detected in these marginal beds, and in such cases they are very little affected by shearing stresses, showing that there has been very little differential movement during the folding.

Large rounded masses or short veinlets of quartz are sometimes observed at the junction with the sill, and even within the margin of the originally igneous rock.

These marginal beds may be repeated by folding, so that they cover a considerable area, but where a good section is examined they can always be proved to be only a few feet, or perhaps only a few inches, thick.

Where the Quartzite lies at a higher horizon than the sill, and the sill is enclosed by black schist on both sides, none of the above phenomena are noticed, either at the margin of the quartzite or at the margins of the sill.

From this evidence it seems probable that this sill has been intruded prior to the deposition of the quartzite, that the latter rests unconformably upon it in many localities, and that the basal layers of the arenaceous rock contain material derived from the denudation of the originally igneous rock.

Turning to the evidence from the large parent sill or laccolite, some confirmation of this view is found, but till the ground has been fully surveyed, it is impossible to speak conclusively.

It has been seen that the black schist has been hornfelsed by the intrusion, and that this alteration can still be detected. Now in several localities the base of the quartzite traverses the outcrop of the black schist and comes in contact with the hornblendic intrusion. In such cases no induration of the quartzite has been observed, but, on the contrary, the marginal beds present a rusty decomposed aspect, containing many impurities. In one and the same locality this rusty edge of the quartzite may be seen in contact with both the hornfelsed black schist and the coarse hornblendic sill.

In one or two localities also the base of the quartzite appears to traverse the outcrop of this sill or laccolite, and comes in contact with the underlying Ben Lawers schists.

The area examined is singularly free from faults of any magnitude and from igneous intrusions older than the folding.

The folding is never very deep, but is perfectly isoclinal. The area comprises part of the centre of the great fan structure of the southern Highlands; in consequence there has been none of the later shearing movements, and the grade of dynamic metamorphism is low, the shearing consequent on the folding being the only movement of the kind to which the rocks were subjected, with the exception of some strain slip cleavage developed in the finer and softer schists.

Where the thinnest edges of folds of the quartzite are enclosed in the black schist considerable evidence of shearing movement

is observed, but within a few feet the quartzite becomes fairly massive, and pebbles are often very little drawn out. Mr. Craig.

In the area to the south of this district where the folding is flat or gently inclined, no traces of pebbles can be seen for a distance of from six to ten miles from this central axis.

The thermometamorphism is considerable, though nowhere intense; aluminous silicates have not been developed in the argillaceous rock, nor calc-silicates to any extent in the limestones, but all the rocks have been recrystallised.

Strath Tummel District.—The results of the re-examination of about 15 square miles of ground in the lower portion of Strath Tummel are thus given by Mr. Wilson. Mr. Wilson.

From south to north the various zones are found in the following geographical order—

- (4) Limestone and black schist.
- (3) Quartzite.
- (2) Black schist with little black limestone.
- (1) Ben Lawers schist.

(2) *Black schist with little black limestone.*—The greater portion of this group is a dark-blue schist. At some localities these dark bands alternate with grey schists with garnets, and occasionally the series becomes coal-black towards the top and contains graphite. The little black limestone is situated in this group.

(3) *Quartzite.*—This division varies from a solid white quartzite to pebbly quartzite and quartz-schist.

(4) *Limestone and black schist.*—The limestone is a blue to steel-grey holocrystalline rock, and the black schist is identical in every respect with the dark blue and black schists of group 2.

(1) *Ben Lawers schist.*—On the east side of the Frenich Burn there is a small area of these schists, which are entirely composed of large bladed crystals of actinolite in a sericitic base. The actinolite schist, along with the spotted brown limestone, forms a characteristic band at the top of the Ben Lawers schist. On the craggy ridges to the west of Pitlochry the upper and calcareous portion of this group contains two well-marked infolds of the black schist.

(2) *Black schist.*—To the west of the River Tummel at Pitlochry no alteration has been made on the previously traced outcrop of this group, but the occurrence within it of the little black limestone was proved at two different localities. From this southern outcrop, at a point one mile west of Farragon, the black schist has been traced continuously across the watershed into Strath Tummel, where it stretches from near the head of the loch to a distance of two miles below its outlet. All through Strath Tummel the different members of this zone are constantly repeated by the shallow isoclinal folds. As the result of this folding the boundary lines are much involved. The small black limestone and black tremolite rock has been observed at several localities within the area to the south of Loch Tummel.

On the north side of the river and loch this same zone of black schists has been continuously traced from the foot of Glen

Mr. Wilson. Fincastle to a point north of Portnellan House, where it is truncated by the Loch Tay fault. This area of black schist is only separated from the outcrop of the Blair Atholl limestone and its black schist on the watershed between the Rivers Tummel and Garry, near Lochan na' Leathain, by a narrow belt of ground obscured by superficial deposits 300 yards wide, and there is a strong presumption that the black schist is continuous across.

To the north-east of the large Strath Tummel belt, and separated from it by quartzite, another area with a very irregular boundary stretches from near Fincastle House to the River Garry, and is continuous with the black schist mapped by Mr. Cunningham-Craig on the east side of this river, and several small inliers occur within the quartzite at the foot of the Tummel Valley.

(4) *Limestone*.—Within the area of the black schist already described as extending west to the Loch Tay fault, and about a quarter of a mile east of Loch Tummel Inn, the cliff called Creag Mhor is formed of a mass of steel-grey limestone, identical in character with the Blair Atholl limestone as developed a little to the north-east at the head of Glen Fincastle, and there can be little doubt that it is a western extension of that seam. In this exposure the limestone is visible in three separate folds surrounded by and folded with the black schist. In the immediate vicinity of Creag Mhor there are two other separate outcrops of a similar limestone associated with the same belt of black schist.

At the head of Glen Fincastle near Edintian and the black schists, there is a considerable outcrop of black limestone, which has been recognised by Mr. Wilson as the "little black limestone." He regards it as the same limestone which occurs in the southern outcrop, and from this correlation as a necessary consequence, the identity of the black schist in the two areas follows. The triangular area on the south side of the River Garry is occupied by Blair Atholl limestone and black schist, and there can be no doubt we are dealing with the same black schist and limestone as at Creag Mhor, because at the head of Glen Fincastle, the little black limestone and black schist both dip under the Blair Atholl limestone.

Quartzite.—The character of this rock varies considerably over this area. To the S.E. of the junction of the Tummel and Garry on both sides of Loch Tummel, and at several other localities, the black schist is immediately overlaid by a solid white quartzite containing felspar. In the direction of Farragon, this massive type gives place to a grey quartzite with strong pebbly bands, either at the edge or else some little distance from it. The grey colour is due to small lenticular fragments of black schist which are enclosed in the quartzite matrix. This fact seems to indicate that local denudation of the black schist was taking place at some point or points in this district, during the period of deposition of the quartzite.

At several points in Strath Tummel, the edge of the quartzite next to the black schist is slightly calcareous, and generally occurs as a weathered crumbling gritty rock. The

pebbly edge of the quartzite is found as far as Loch Tummel, and Mr. Wilson on both sides of the belt of black schist which extends northwards from Farragon. From Glen Fincastle to the Pass of Killiecrankie, the quartzite is very much folded and inter-felted with bands of black schist. Here the edge rock of the quartzite is essentially a quartzose schist with a rusty brown weathering, and frequently contains biotite, tourmaline, and other minerals.

Basic intrusions.—Throughout the pass of Killiecrankie, a much folded epidiorite sill with garnets (sometimes 1 inch in diameter) is associated with the black schist. This sill occurs at many points to the west, and as far up Strath Tummel as the foot of the loch. It is sometimes intrusive in the black schist, but is more frequently in close contact with the quartzite on the one side, and the black schist on the other.

Relation of the Quartzite to the other Zones.—The occurrence of black schist fragments in the pebbly quartzite has already been mentioned as evidence in favour of the view that local erosion of the black schists took place in the present region during the deposition of the quartzite. At Creag Mhor the quartzite is seen to transgress from the Blair Atholl limestone on to the black schists. To the north of this point, the same edge of the quartzite is successively in contact with the Blair Atholl limestone and with the black schist for a short distance. Over the portion of the area (already described) occupied by the pebbly edge of the quartzite, the latter occurs next to the black schist, but at the French Burn, this pebbly edge for some distance is in contact with the "Ben Lawers schist," exposed in the small area already noticed.

Within the triangular space on the south side of the River Garry occupied by black schist and Blair Atholl limestone there is a considerable area of solid white quartzite, the outer edge of which rests on black schist and the inner edge on limestone. This same belt of limestone passes outside the quartzite and is then on both sides in contact with black schist.

These facts afford strong presumptive evidence in favour of an unconformability between the quartzite and the other members of the Highland schists in this area.

II. PALÆONTOLOGICAL WORK.

Mr. Peach, the Acting Palæontologist, has prepared the following summary of palæontological work in Scotland during the past year. Mr. Peach.

The Palæontological department in Scotland was carried on during the season by Mr. Peach, assisted by Dr. C. B. Crampton, Mr. A. Macconochie, and Mr. D. Tait. Assistance had also been afforded by the following specialists outside of the Geological Survey, viz., Dr. Traquair, Dr. Wheelton Hind, and Mr. R. Kidston.

The number of fossils gathered by the Fossil Collectors during the year is 1191, of which 31 are from the Ludlow and 74 from the Downtonian rocks of Lanarkshire, 20 from the Lower Old

Mr. Peach. Red Sandstone of Fife and Dumbarton, 298 from the Carboniferous rocks of Berwickshire, Fife and Arran, 719 from the Secondary rocks of the Isle of Skye, and 50 from the Post-Tertiary Clays of Loch Lomond. During the season the fossil collectors were much engaged in collecting rock specimens, which they gathered to the number of 2,693. In view of the publication of the memoir on East Fife Sir Archibald Geikie desired that collections of fossils should be made from certain shaly beds of the Lower Old Red Sandstone that emerge from beneath the great volcanic platform of the Ochils and are exposed on the shore of Wormit Bay on the south of the Firth of Tay nearly opposite Dundee, and also from Parkhill in the same neighbourhood whence Professor Fleming obtained the first described specimens of *Parka decipiens*. Collections were accordingly made by Mr. Macconochie. The fishes, determined by Dr. Traquair, are *Mesacanthus Mitchelli*, *Ischnacanthus gracilis*, and *Climacodus scutiger*; the other forms, determined by Mr. Peach, are *Pterygotus anglicus*, *Eurypterus* sp., and *Parka decipiens*. The assemblage of fossils is like that found at Duntrune and Balruddery on the opposite side of the Firth.

For the same purpose it was found to be highly desirable that certain plant bearing beds in the Lower Carboniferous rocks exposed on the shores of East Fife should be specially searched for plants. Mr. Kidston, accompanied by Mr. D. Tait, devoted a few days to this investigation, with the result that they obtained a considerable amount of material. The results of Mr. Kidston's study of the plants obtained will be incorporated in the forthcoming memoir. One of the plants, *Sphenopteris foliolata*, Stur., obtained by them is new to Britain.

At the instance of Mr. Gunn, and for the purpose of obtaining additional information for the forthcoming memoir on the Geology of part of Arran, Mr. Tait made a collection of fossils from the shingle beach on the north side of Catacol Bay, in Arran, as Mr. Gunn thinks that there is strong presumptive evidence that Carboniferous Limestone rocks occur in the sea just outside of Catacol. Mr. Peach determined the fossils, which appear to denote the horizon of the Upper Limestone group of the Carboniferous Limestone series of Scotland.

In order to follow up the discoveries made in the Ludlow and Downtonian rocks of Lanarkshire, Mr. Tait in the early part of the season made a considerable collection from these rocks in the Lesmahagow inlier in Lanarkshire. The fishes have been determined by Dr. Traquair, but no new points of morphological interest have been exhibited by the specimens. Several good specimens of *Pterygotus* and *Slimonia* were obtained by Mr. Tait from the site of the Logan Water Reservoir at present in course of construction.

In the autumn Mr. Kidston once more placed his valued services at the disposal of the Geological Survey, and, accompanied by Mr. Macconochie, made a search for rare fossil plants among the lowest Carboniferous rocks of the Border. The results are embodied in the accompanying report by Mr. Kidston.

While searching for plants they also obtained a valuable collection Mr. Peach. of fossil crustacea. They also made a very interesting discovery of pseudomorphs after crystals of salt in some shales of the Cementstone group of the Lower Carboniferous "Tuedian Beds" exposed in a scur of the Blackadder Water near Allanton, in Berwickshire. The particular interest attaching to the find is the additional evidence this affords in favour of the view of the Cementstone phase of the Lower Carboniferous rocks being deposited in concentrated saline waters.

The following is Mr. Kidston's Report on fossil plants gathered from the Calciferous Sandstones of the Berwickshire border:—

"From the great interest of the specimens collected last year in Mr. Kidston. Berwickshire (see Report for 1900, p. 174), a second visit was made towards the end of last season with the object of further investigating the fossil flora of the Calciferous Sandstone Series. The results were very satisfactory, and again led to the discovery of some new and interesting species.

"Specimens were collected from the following localities:—

"From the Whiteadder Water, right bank, scur under Edrom Church. (This locality is described in first notes, p. 174, as 'Right bank of Whiteadder, one-fourth mile west of Edrom House,' but the above designation is more definite.)

"To those recorded from this locality last year the following must be added:—

Sphenopteris elegans, Brongt.

This is the *Sphenopteris* sp. of first list.

Lepidodendron Veltheimianum, Sternb.

This is probably the *Lepidodendron* sp. of first list.

Stigmaria ficoides, Sternb. sp.

Cardiocarpus bicaulatus, Kidston.

"From right bank of Whiteadder Water at Willie's Hole, one mile east of Allanton. (In previous notes designated as from 'Right bank of Whiteadder, three-quarters-of-a-mile below Allanton'):—

Marchantites sp. Distinct from that already noted.

Lepidodendron Veltheimianum, Sternb.

Stigmaria ficoides, Sternb. sp., var. *undulata*, Göpp.

"From Road Cutting, north end of Norham Bridge over Tweed, a *Neggerathia*-like pinnule was found in the upper portion of a cement stone band about twelve inches thick, in the shales a few feet above the level of the road.

"Some material showing plant structures was also collected, but this has not yet been examined.

"From small stream, about a quarter-of-a-mile N.E. of Ladykirk:—

Asterocalamites scrobiculatus, Sch. sp.

Mr. Kidston. "From Blackadder Water, right bank, about a quarter mile above Allanton Bridge:—

Lepidodendron spetsbergense, Nath.

"From Whiteadder Water, Bellsburn Scaur, near Chirnside:—

Aneimites sp.

"From Langton Burn, about four hundred yards N.N.E. of Gavinton, near Duns:—

Lepidodendron spetsbergense, Nath.

"Marshall Meadows Bay, two-and-a-half miles north of Berwick.

"These beds are above the Scremerston Coals, and below the position of the Hurlet Limestone:—

Sphenopteris (Diploehmema) Schutzei, Stur.

Cardiopteris polymorpha var. *rotundifolia*, Göpp. sp.

Asterocalamites scrobiculatus, Schl. sp.

Pinnularia.

Lepidodendron Veltheimianum, Sternb.

Lepidostrobus.

Stigmaria ficoides, Sternb. sp.

"The specimens of *Asterocalamites scrobiculatus* were very fine, some being about a yard long. The *Stigmaria* showed the attached rootlets very beautifully, the rhizomes not being crowded, the rootlets were seen to extend from them at right angles, and about a foot long where they were broken over. Several rootlets were found which ended in a bifurcation.

"In addition to the two localities mentioned in the Report for 1900, viz., Langton Burn Road Cutting, north end of Norham Bridge, from both of which additional material was collected, some small blocks of a shelly limestone were found in the shingle on the Whiteadder Water immediately below the right bank scaur under Edrom Church.

"The plant remains in these are not so well preserved as those in the Langton Burn material, but the blocks contain much the same species. The Edrom material has, however, yielded a *Heterangium*, a genus not previously met with in Berwickshire.

"Microscopic preparations are at present being made from these materials showing plant structure, and already about one hundred and fifty slides have been prepared; but still a considerable amount of material awaits examination, so a Report on these specimens will be deferred for a future occasion. It may be mentioned, however, that the plants are of very great interest, and have added much to our knowledge of palaeozoic botany."

A large collection of fossils was made by Mr. Tait from the Mr. Peach. Secondary rocks of the Isle of Skye during the season, to assist the Surveyors in fixing the horizons of these rocks as developed in Sheet 71 (one inch). They include fossils from each of the sub-divisions from the Infra-Lias or local representative of the Rhaetics up to the Oxford Clay. These fossils have all been sent to Mr. E. T. Newton for determination and classification. A few specimens of fossil wood showing structure collected from beds which may be of Triassic age have been submitted to A. C. Seward for examination. During the season a most interesting and important discovery was made by Mr. Clough who, as already stated in a former part of this report (p. 146), found cherty rocks in beds underlying the great Tertiary volcanic plateau in Skye, on the north side of Soay Sound in Sheet 70 (one inch). According to Mr. E. T. Newton, to whom the specimens were submitted, the cherts contain fossils which appear to belong to the Greensand division of the Cretaceous, an opinion also shared by Dr. G. J. Hinde (see p. 92).

Mr. Cunningham Craig, who surveyed the islands in Loch Lomond, wished a further collection of shells to be made from the Glacial Clays of Inchlonaig, which he considers to be of the age of the Hundred-feet Beach. Mr. Macconochie was, therefore, detailed to make the collection, which has been submitted to Mr. E. T. Newton, and a list of about 20 species has been supplied to Mr. Cunningham Craig for insertion in the forthcoming memoir of Sheet 38 (one inch).

Mr. Macconochie obtained from the Calcareous Sandstones on the banks of the Whiteadder, near Dunse, specimens of a fish spine in addition to one he had collected from the same locality many years before. The spines are considered by Dr. Traquair of sufficient interest to warrant the construction of a new species of *Gyracanthus*, the description of which by him is here given:—

Gyracanthus falciformis n. sp. Traquair.—Length, four and a half to six inches; very decidedly and evenly curved antero-posteriorly from base to apex; stout at the base and rapidly tapering to the point. Inserted portion short, exposed part covered with closely set oblique ridges which get more and more oblique, till towards the point they are nearly parallel with the posterior margin of the spine; ridges tuberculated near the base, but tending to become quite smooth towards the apex. Posterior area narrow; unsymmetrical as usual; each of its margins being set with a row of very small oblique denticles. Dr. Traquair.

“The well marked configuration of these comparatively small spines (of which there are three pretty entire specimens in the Survey collection) prevents me from considering them to be the immature form of any known species.”

Lists of fossils were drawn up by Mr. C. B. Crampton and Mr. Mr. Peach. D. Tait, under the supervision of Mr. B. N. Peach, for the Appendix of the East of Fife Memoir.

Mr. Peach.

The following is a list of Specimens in the Survey collection figured in the Paleontographical Society's volume for 1901:—

A Monograph of the British Carboniferous Lamellibranchiata by WHEELTON HIND. Vol. ii, part 1.

Pteronites angustatus from Lower Carb. Series, Lawston Linns, Liddle Water. Plate v., fig. 1.

Pteronites angustatus from Cale. Sa. Series of Glencartholm, Dumfriesshire. Plate v., fig. 4.

Actinopteria fluctuosa from Clecklinon, Kilbride. Plate v., fig. 8.

„ „ from the first limestone on the shore E. of Kinghorn. „ Plate v., fig. 2.

Actinopteria fluctuosa from W. Quarry at Salton. Plate v., fig. 12.

Posidonomya corrugata from near Paisley. Plate vi., fig. 3.

„ „ *radiata* from Calcif. Sa. Glencartholm, Dumfriesshire. Plate vii., fig. 7.

A Monograph of British Graptolites by G. L. ELLES and E. M. R. WOOD, edited by C. Lapworth. Part 1. Dichograptidae.

Didymograptus serratulus from Minnoch Water, Glencaird Lodge, S. Scotland. Glenkiln Shales. Plate ii., fig. 7.

The Ganoid Fishes of the British Carboniferous Formations by R. H. TRAQUAIR. Part 1. Paleoniscidae.

Elonichthys pulcherrimus (scales only). Plate xii., fig. 2.

„ „ *serratus* (scales only). Plate xii., fig. 6.

III. MUSEUM WORK.

Mr.
Goodchild.

The Curator of the Geological Survey Collections in the Edinburgh Museum of Science and Art, reports that during the year now at a close, the principal work done in the Geological Survey Gallery has been the re-arrangement of a large part of the collection of rock specimens, and the intercalation amongst these of new specimens of interest collected by the Survey officers, or given by others. A large number of the specimens of fossils have been retabulated, and the descriptions written anew. In the course of this work the figured specimens have received special attention. A number of specimens of fossils from the Clyde Beds have been mounted and placed on exhibition. In addition to this, the important work of arranging the part of the collection which is not exhibited has been carried on. These specimens are arranged primarily under their respective biological headings, and secondarily under the number of the Ordnance Survey one-inch Sheets, so as to be available for immediate reference for lists. The collection of rock specimens placed in the glazed cases beneath the maps, has been catalogued with the special object of facilitating reference to such of the specimens as may be duplicates.

During the year the third edition of the Guide to the Geological Survey Collections was sold out, and a new edition was forthwith prepared and placed in the hands of the Director of the Museum for publication as before.

IV. MAPS, Etc., PUBLISHED.

Two sheets of the one-inch map have been published during the year, viz :—

- No. 21, the northern part of Arran, part of Bute and the Cumbræes.
No. 38, embracing the districts of Loch Lomond, Loch Katrine and Callander.

Extra Official Publications, 1901.

BARROW, G.—“On the occurrence of Silurian (?) Rocks in Forfarshire and Kincardineshire, along the Eastern Border of the Highlands.” *Quart. Journ. Geol. Soc.*, vol. lvii., p. 328.

GUNN, W.—“On the Old Volcanic Rocks of the Island of Arran.” *Trans. Geol. Soc. Glasgow*, vol. xi., p. 174.

—————“On Recent Discoveries in Arran Geology” (read at British Association meeting, Glasgow). *Geol. Mag.*, Sec. IV., vol. viii., p. 565.

HARKER, A.—“Ice Erosion in the Cuillin Hills, Skye.” With map. *Trans. Roy. Soc. Edin.*, Vol. xl., part II., pp. 221-252.

—————“The Sequence of the Tertiary Igneous Rocks of Skye.” *Geol. Mag.*, (4), vol. viii., pp. 506-509.

HILL, J. B.—“On the Crush-Conglomerates of Argyllshire.” *Quart. Journ. Geol. Soc.*, vol. lvii., pp. 313-327.

KYNASTON, H.—“On some tuffs associated with the andesites of Lorne.” *Trans. Edin. Geol. Soc.*, Vol. viii., pp. 87-90.

PEACH, B. N. ; W. GUNN, and E. T. NEWTON.—“On a remarkable Volcanic Vent of Tertiary Age in the Island of Arran, enclosing Mesozoic Fossiliferous Rocks.” *Quart. Journ. Geol. Soc.*, vol. lvii., p. 226.

III.—IRELAND.

I.—FIELD WORK.

DUBLIN DISTRICT.

Mr. G. W. Lamplugh, District Geologist.	
Mr. J. R. Kilroe,	} Geologists.
Mr. A. McHenry,	
Mr. H. J. Seymour,	
Mr. W. B. Wright,	

The mapping of the drifts on the six-inch scale in the neighbourhood of Dublin was commenced in May, and the area represented on the one-inch Sheet 112, with so much of the margin of the adjacent sheets as lay within the slips of the six-inch maps required to complete that sheet, was completed by the end of November, the total area surveyed being 156 square miles. Attention was devoted exclusively to the drifts and other superficial deposits, though in traversing the ground a few facts were

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noted in regard to the solid rocks which will be useful in preparing the new edition of the Memoir on Sheet 112, this memoir being at present out of print.

The MSS. six-inch maps of the former "solid" survey were examined, and a few notes relating to the drifts were transferred from them to the new working six-inch field-maps, but it was found that these notes were too scanty and the sketch-boundaries originally drawn for the drifts too diagrammatic to yield any material aid in the preparation of the drift-map. It has therefore been found necessary to make a thorough re-examination of the ground so far as the superficial deposits were concerned, but this has occupied much less time than would have been required if the re-examination of the solid rocks also had been undertaken. Notes were made on the field-maps as to the present state of the land, whether under grass, tillage, etc., and also as to the character of the soil, so far as this could be determined by traverse only.

It was observed that in this district, as in most parts of the United Kingdom, the area under tillage has evidently decreased greatly of late years, while the area of grazing land has correspondingly increased, and is largely occupied by dairy farms, from which a large proportion of the milk-supply of Dublin is drawn.

The greater part of the area in Sheet 112 is an undulating plain of Lower Carboniferous rocks more or less deeply drift-covered, but the southern side includes the northern margin of the Leinster Granite, with strips of the Older Palæozoic rocks fringing the granite on the east and on the west, and in this district the ground becomes mountainous and the drifts more irregularly dispersed. The plain is trenched by the valleys of the Tolka, Liffey and Dodder Rivers discharging into Dublin Bay, while the easterly part of the hilly tract is drained by small streams falling into Killiney Bay. On the north side of Dublin Bay the rugged peninsula of Howth with its attendant islet of Ireland's Eye, composed of the Older Palæozoic rocks, lies within the sheet. The shape of the ground has profoundly influenced the characters and mode of occurrence of the glacial deposits, so that the study of the physiography and of the glacial geology of the district are closely interlinked.

The area surveyed was divided out among the members of the field-staff as follows:—Mr. Kilroe mapped the district extending from the south-west suburbs of Dublin to the southern margin of the sheet, including the coast-line from Merrion through Kingstown to the south side of Killiney Bay (six-inch Sheets 23 and 26), and also an inland tract on the lower slopes of the Dublin Mountains extending westward to Rathfarnham (eastern half of Sheet 22). Mr. McHenry examined the central district (six-inch Sheet 18), including the City of Dublin and its suburbs northward to the Tolka Valley and westward along the Liffey Valley to Chapelizod, with the ground to the southward (western half of Sheet 22) up to the foot of the hills, and westward north of Tallaght to the margin of the map (north-east corner of Sheet 21). Mr. Seymour and Mr. Wright divided between them the northern and western margin of the map from Howth westward

beyond Blanchardstown (S. part of six-inch Sheets 13, 14, and 15, with Sheet 16), and thence southward to Clondalkin (E. part of Sheet 17); these officers likewise surveyed the mountainous ground on the south between Glenasmole and Stepaside (north part of six-inch Sheet 25). Mr. Lamplugh mapped a small tract in the extreme south-west corner of the sheet (parts of six-inch Sheets 21 and 24), and also undertook general charge of the field-work, instructing and advising the officers in respect to the mapping, and inspecting the work when done.

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The previous literature relating to the drifts of this district is extensive, the fine coast sections and the high-level shelly gravels of the mountain slopes having received especial attention. In the forthcoming memoir full reference will be made to this literature, and meanwhile it will suffice to mention that among the chief contributors to the subject have been the Rev. Maxwell H. Close, J. Kelly, the Rev. Canon Grainger, G. H. Kinahan, Prof. E. Hull, A. Bell, T. Mellard Reade, Prof. W. J. Sollas, and R. Lloyd Praeger.

In order to make clear certain detailed results to be afterwards recorded, which were obtained severally by the above-mentioned officers, it will be advisable to give first a brief outline of the broader features of the drift deposits of the neighbourhood of Dublin.

From the northern margin of the map up to the foot of the mountains, the prevailing material is a tough dark boulder-clay, highly calcareous, both in the matrix and in the included stones. This boulder-clay represents the crushed material of Carboniferous Limestone and its accompanying shales, but it usually contains also a few fragments of Silurian grit, Old Red Sandstone, and various intrusive rocks transported from beyond the limits of the limestone. Though moulded upon or against the bolder rock-features, it fills up and obliterates all the minor inequalities of the rock-surface, forming smooth gentle slopes descending gradually toward the main drainage hollows of the inland districts and eastward toward the sea. It appears at one time to have obliterated all the minor stream-courses of the district, and also the sharper features of the principal river-valleys, the present streams having in most cases re-excavated channels through the boulder-clay which sometimes coincide with their former rock-channels and sometimes do not. The smooth featureless surface of the boulder-clay usually gives no indication as to the thickness of the drift, the solid rock being in some places within a foot or two of the surface, while in other places it may be buried to a depth of 100 feet or more; it is usually found, however, that the deposit is thickest at the lower level, and thins away toward the crests of the smooth rounded swells which form the minor watersheds of the Carboniferous plain, so that on these crests the rock is often only thinly sprinkled with drift. The limestone also crops out in a few curiously bold bosses along the northern margin of the map,

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where massive pale crystalline limestone having the much discussed "knoll-structure" occurs among the thinly-bedded shaly Calp Limestone. Glacial striae were observed in numerous places beneath this boulder-clay, and these indicate a general movement of the glaciating agent from about N.N.W. to S.S.E. over the plain, *i.e.*, from the interior toward the sea. As will presently appear, however, this direction changes on the eastern flank of the mountains; and both to the northward and southward of the present map the striae indicate an ice-flow roughly parallel to the present coast-line.

The homogenous character of the boulder-clay is lost as we leave the limestone plain and enter the granite country, owing, in the western part of the district, to the admixture of granitic and other local detritus (which curiously hugs the slope of the hills and never extends beyond a very short distance on the plain), and in the eastern part to the incoming of a boulder-clay of different composition which appears partly to replace and partly to underlie the limestone-clay.

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Disconnected patches of stratified drift-material make their appearance here and there over every part of the drift-plain, and evidently represent the local sifting of the ice-borne detritus by flowing water. This local sifting has taken place during the accumulation of some of the boulder-clay as well as in later times. In the former case the assorted material has probably been derived directly from the melting ice, and in the latter from the washing down of the previously deposited clay. It has, therefore, been found possible in most cases to make a rough classification of the gravels according to age, though in places where gravels of different age are conterminous their separation was scarcely practicable.

On the drift-plain north of the Liffey the stratified material occurs chiefly in elliptical mounds or short ridges, sometimes arranged in clusters and sometimes rudely lineated, and often associated with outcrops of the solid rock-floor. Owing to the clayey character of the residual soil formed from the decay of the more or less argillaceous limestone-pebbles which preponderate in the gravels, there is frequently little or no surface indication that these mounds differ in composition from the surrounding boulder-clay tract; but so many open sections of gravel and calcareous sand were observed in them that there can be little doubt these mound-features, where not caused by bosses of solid rock, are nearly always due to the presence of a core of stratified drift, and that in this district there are few or no true "drumlins" of boulder-clay. These mound-gravels may rest either on boulder-clay, or on the solid rock. In three or four instances where sections were exposed, their lower flanks were seen to be enwrapped and covered by the higher portion of the boulder-clay, with a more or less gradual passage downward and inward from the unstratified into the stratified drift. The bedding of the mounds is generally arched in the same direction, though not so steeply as the surface. They present, in short, all the usual

"kame-structures," and must be closely associated in age and mode of origin with the continuous esker-ridge south of the Liffey, next to be noticed. Mr. Lamplugh.

The most northerly indications of this esker, in the country examined, appear to be the irregular gravel mounds and ridges seen on both sides of the Liffey Valley near Chapelizod, but the continuous embankment-like ridge sets in at Drinnagh, about a mile further south, and runs southward thence with a sinuous course for nearly three miles, to the Dodder Valley, while its prolongation south of that river is again indicated by broken mounded ground, trending now to the eastward. The characteristic esker-structure is beautifully displayed in the numerous large gravel-pits opened into this ridge. Though usually resting on boulder-clay this esker crosses a low ridge of limestone about mid-way in its course, and the fortunate occurrence of a deep pit at this point reveals new evidence of much interest. It is here seen that the gravel in the middle of the ridge rests upon a battered and water-worn floor of limestone, but that a few yards outward, towards the western side of the esker, the bottom gravel passes into gravelly clay full of scratched stones, resting upon a well-scratched rock-surface.

Here, then, is definite proof that at this point the waters carrying the gravel were at ground-level, and also apparently that they were hemmed in by ice at the margin of the ridge.

In approaching the mountains the drifts show a rapid increase in stratified material, and at the highest levels they usually end off upon the hills of granite and slate in thick irregular masses of sand and gravel, composed of the materials of the limestone-drift mingled with local detritus and with a few far-travelled stones. The presence of shell-fragments in this portion of the drift, at elevations up to 1,200 feet, has been the subject of much discussion, and is usually held to imply a submergence of the land to this extent; but the position, mode of arrangement, and contents of shell-bearing drifts, as well as the general tenour of the physiographical evidence, is quite incompatible with the view that they represent marine deposits; while on the other hand the facts all converge to prove that we are dealing with the marginal phenomena of an ice-sheet.

Excellent sections exhibiting the relationship between the high-level and low-level drifts are exposed in the high river-banks of the Dodder in Glenasmole, and in the glens of the mountain streams which join the Dodder at Rathfarnham. At the edge of the plain these usually show the intercalation of gravel, sand and silt between two boulder-clays, and the rapid thickening of the stratified material, at the expense especially of the upper boulder-clay in passing up the valleys, until finally the upper clay disappears entirely. The gravels then occupy the surface in a mounded belt, overlapping the lower clay and ending off on the slopes or in the high cols of the solid rock. Similar phenomena on a smaller scale are seen on the northern side of the rocky promontory of Howth, where a thick shell-bearing sand and gravel, banked against a rock-slope

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opposite the mouth of a wide hollow, is seen to fade out laterally between two boulder-clays. Where dominated by steep rock-slopes, the drifts are usually overspread and more or less inter-mixed with local rubble, which appears to have been washed down the hillsides by rain and floods both during and after the formation of the upper part of the drifts.

Besides the gravels associated, as above described, with the boulder-clay, there are, in several parts of the district, tracts of gravel of later age, but still of considerable antiquity. These gravels overspread the drifts in flat sheets occupying comparatively low and depressed ground, but yet usually outside the confines of the present river valleys. They are clearly associated with the rapid denudation which took place when the land was once more laid bare, but before the streams had re-excavated proper channels and were comparatively unconfined. The largest tract of this kind in the present map lies immediately to the south of Rathfarnham, and represents the gravels suddenly thrown down by the flooded mountain-streams on reaching the foot of the slope. From the gravels of this character to the high-level river gravels there is often but a step, and the latter descend by successively lower terraces to the recent alluvium, as is excellently seen in the valleys of the Dodder and the Liffey. Thus, from the period of deposition of the high-level drifts to the present time, there is clear proof of uninterrupted land conditions, except in a narrow strip along the coast-line where an ancient sea-beach, raised a few feet above present high-tide level, is distinctly marked.

A striking but hitherto neglected peculiarity of the district around the foot of the mountains, is the presence of numerous short, deep, water-cut gorges with precipitous walls, notching across projecting spurs of the granite and slate rocks in positions where, under existing circumstances, no stream could flow. These are now either quite dry or occupied only by a mere trickle of the rainfall-water collected within them. There seems to be no other possible explanation for these gorges than that they were excavated by powerful streams either draining directly across the ice-sheet or representing the overflow from the small lakes held in between the hills on the one side, and the margin of the ice-sheet on the other, after the manner made familiar by the recent geological explorations in Greenland and Spitzbergen.

In the S.W. corner of the map, notches of this kind are conspicuous on the slopes of Slievenabawnoge; on the opposite side of Glenasmole a very fine example, with walls 90-100 feet high, cuts the ridge south of Montpelier House at an elevation of 1,035 feet; others occur on the lower spurs of Three Rock Mountain; and a small but typical example at a lower elevation gashes the low ridge of granite one mile south of Carrickmines.

Advantage may be taken of this opportunity to state, with little hesitation, that the picturesque and much-visited gorges of The Scalp and The Glen of the Downs, lying respectively one mile and seven miles to the southward of the margin of the district at present under examination, may be assigned to the

same agency, and that these exhibit the characteristic features of "overflow channels" on the grandest scale. Mr. Lamplugh.

The study of the present river-valleys of the district has yielded some instructive results in regard to its post-glacial denudation. The pre-glacial valleys of the Liffey and the Dodder, within Sheet 112, appear to have coincided in most places with the present valleys, so that these streams have been mainly occupied since glacial times in clearing out the drift-material with which they were choked. Here and there, however, they have swerved from the original channels in the process; as, for example, at Palmerston where the Liffey at its sharp elbow has cut a deep ravine in the Carboniferous Limestone, while there are indications that its drift-filled pre-glacial channel lies a little to the northward of the present river. The southerly tributaries of the Dodder appear also for the most part to be following their old courses; with an occasional striking divergence, as where the little stream from Piperstown swings away from its drift-filled depression and plunges through a deep chasm across the spur of slate to join the Dodder near Fort Bridge. But in the irregular ground between the southern shore of Dublin Bay and the mountains, the old drainage system is much confused, and the streams have carved new channels for themselves in the granite in many places. North of the Liffey also, the Tolka, for the greater part of its course in Sheet 112, occupies a new channel, cut through the drift into the limestone, and no definite evidence is yet forthcoming as to its pre-glacial course.

The general conclusion to be drawn from the post-glacial work of the streams is that a comparatively long period must have passed since the recession of the ice from the district.

The more important of the local observations of the several members of the Irish staff, with some individual conclusions which have not found place in the preceding *Summary* will now be given.

In the south-western corner of the district, just beyond the margin of Sheet 112, Mr. Lamplugh found that the projecting spur of the mountains lying west of Glenasmole, composed of the slate with igneous intrusions, was in part capped, to a depth exceeding 12 feet in one section, by stiff calcareous till containing many striated boulders of Carboniferous Limestone. This boulder-clay reaches an elevation of over 1,100 feet above O.D., although the steep sides of the spur are free from drift. This is the greatest altitude to which the limestone boulder-clay, as distinguished from the stratified drift, has yet been traced. As the high-level drift usually consists of gravel, sand and local rock-rubble, which many observers hesitate to recognise as glacier-borne, the presence at this altitude of typical boulder-clay which would be generally acknowledged as the direct product of land-ice, is of importance in proving that the ice-sheet must have been sufficiently thick to reach the level of the highest gravels.

In the south-eastern part of the sheet the tract of 32.2 square miles, surveyed by Mr. Kilroe, is mainly underlain by granite, Mr. Kilroe.

Mr. Kilroe. over which the drifts are somewhat irregularly distributed. The following useful table compiled by this officer will serve to show the relative area of the various superficial deposits and of the solid rock :—

		Total area.	Rock.	Local Drift.	Limestone Boulder- clay.	Glacial Sand and Gravel.	Late Glacial Flood-gravel.	Old River Alluvium.	Recent Alluvium.	Intake.
In Six-inch Sheet		Acres.	Acres.	Acres.	Acres.	Acres.	Acres.	Acres.	Acres.	Acres.
	22	7,686	461	562	5,976	69	349	128	141	—
"	23	7,592	670	650	5,866	126	96	29	81	74
"	26	5,330	678	859	3,376	111	25	58	223	—
Total in Sq. Miles.		32·2	2·83	3·23	23·78	·48	·73	·33	·69	·11

With regard to the area shown as bare rock, however, Mr. Kilroe remarks that even here there is usually a sprinkling of grit and limestone pebbles, and that where the rock-surface is uneven, the "pockets" contain transported drift, while a thin, locally-formed clayey rubble occurs in many places where it is necessary to map the ground as rock. The "dry gaps" in the granite south of Carriekmines, to which reference has previously been made, are thus described :—"Two of these cut across the rock-ridge which is separated from the mountains by Kiltiernan valley. They run parallel to each other in a S.E. direction, and in the lowest part present just a noticeable slope towards the south. The more easterly, known as the Dingle Glen, is a steep-sided ravine with a strikingly fresh eastern face of rock, in parts almost vertical, and throughout strewn with recent granite talus. The ground above, sloping gently towards the gap on both sides, is almost bare rock, except on the S.W. side, where it carries a thin coating of local drift. The bottom of the glen, about 50 feet from the crest, is covered with recent alluvium, and near its exit southward occurs a deposit of clay with boulders of limestone as well as granite. That the very recently-formed appearance has been given to this glen by the rush of water attendant upon the melting of the ice sheet there can be little doubt. The deposit of boulder-clay at the southern exit, however, seems to me to preclude the conception that the glen owes its origin to any material extent to glacial denudation. The second glen, Glenamuck, is not so striking a feature, though the origin of both is in all probability identical; and at each end rests a covering of boulder-clay containing grit, black chert and other travelled pebbles, mingled with boulders and talus blocks of granite. Another short gully in the granite near Sandysford, of somewhat different character, must have been in existence before the close of the Glacial Period, as one of its rocky slopes is glaciated."

In examining the frequently-described cliff-sections south of Mr. Kilroe. Killiney, Mr. Kilroe paid close attention to the proposed subdivision of these drifts into "Upper Boulder-clay," "Middle Glacial Sand and Gravel," and "Lower Boulder-clay," but found that these divisions were too changeable and impersistent to be used in mapping the deposits. He observed that bands of more or less stony clay and silt, with all the characteristics of boulder-clay are intercalated and "dovetailed" with the layers of sand and gravel; and found reason to doubt "whether the lowest visible boulder-clay in the whole extended section constitutes the original base of the sand and gravel deposit, if indeed a 'basement clay' in this sense have any existence here." The lowest visible band of clay, however, presents some peculiar characteristics. Though mostly dark grey or slate coloured, some portions of the clay are purple, passing into red, in such a manner as to suggest that the red colouration is due to progressive weathering. "A remarkable feature of the red boulder-clay at one point is, that it contains large irregular *masses* of purple boulder-clay, with sharply-defined outlines—true boulders, in some cases sharply fractured, the gaping cracks being filled with sand, gravel or clay from the surrounding matrix. These clay-boulders show lamination or a flaky structure, and are easily distinguishable from the surrounding red clay when once noticed, not only by a slight difference of colouring, but in this also, that the masses are highly calcareous and the containing clay not so. The stony contents of both—chiefly green grit and slate and granite fragments—are alike, from which, as well as from the fact that some of the enclosed masses show fringes coloured red around cores of purple clay, it is inferred that the red clay is a more highly oxidised form of the purple material. The alteration, however, is not usually by gradual encroachment of oxidation and decalcification from without, but through the matrix having undergone vicissitudes, re-arrangement, &c., not experienced by the included masses."

Mr. Kilroe considers that these remarkable clay-boulders afford material aid in unravelling the history and mode of deposition of the series. He finds that the peculiar boulder-clay which is extensively dug for brick- and tile-making at Kill of the Grange, $2\frac{1}{2}$ miles inland, W.N.W. of Killiney (fully described by Professor Sollas, and Mr. R. L. Praeger in *Irish Naturalist*, Dec. 1895) is "almost if not quite identical with, and strikingly similar to that which composes the included masses of the Killiney section," and therefore concludes "there can be little room to doubt that the masses have been severed from a deposit similar in every way to that at Kill . . . This being admitted, the conclusion is inevitable that the Kill of the Grange deposit dates further back, in the series of glacial episodes, than the Killiney sands and gravels, and is anterior to the *layers* of boulder-clay interstratified with them; and this leads to the further inference that the deposit in question is a true Lower Boulder-clay."

With regard to the sands and gravels of the Killiney section, which, as previous observers have noticed, are steeply tilted in one part of the section, and almost horizontal in another part,

Mr. Kilroe. Mr. Kilroe has noticed some curious features indicating the disturbance and breaking up of the deposits when frozen. "Thus, fissures were formed in stratified sand and gravel, and filled with dyke-like tongues of gravel or of clay, a remarkable example of which is to be seen in the sea-cliff at the railway station at Killiney. What is so remarkable in this instance is that while the clay-tongue is obviously stratified and the stratification is further marked by an included layer of gravel, the fissure seems to have been filled from beneath, a circumstance difficult to explain." In another place it was found that the red boulder-clay above described had been curiously invaded by coarse unstratified gravel or shingle, which had filled a gap about eight feet wide: the margins of the gap were vertical, and sharply jagged and rent, the shingle passing insensibly upward into stratified gravel which was in turn capped by an upper sandy clay. These and kindred facts lead Mr. Kilroe "to picture the phenomena attendant upon the decline of glacial conditions in this (Killiney) district as follows:—

- 1st.—A lower boulder-clay, broken up and denuded in connection with the formation of—
- 2nd.—Sands, gravels and boulder-clay layers.
- 3rd.—Breaking up of boulder-clay layers, and rearrangement of gravels.
- 4th.—Pipes, guts, or pot-holes in 3rd series.
- 5th.—Continuation of sand and gravel deposit.
- 6th.—Upper clay.

"Perhaps the best way of accounting for the sequence of phenomena, thus shown to be in some sense recognisable, is, by conceiving that, following the deposition of the lower boulder-clay, and during the melting of the great sheet of land-ice, there were deluges which carried off the finer matter (clay, silt, &c.), and deposited layers of stratified gravels, alternating with unsorted materials now forming boulder-clay; and, possibly, also temporarily-formed lakes with frozen margins, in which were laid down the finer sediments, into which stones were occasionally dropped from small floating ice-rafts or bergs." The detached clay masses are considered to have been torn from steep banks of frozen clay, eroded by these floods. Mr. Kilroe is opposed to the view that the recurrence of boulder-clay among the sand and gravel is here attributable to alternating advances and retrocession of the margin of the ice sheet.

The presence of marine shells, mostly fragmentary, which are sparsely scattered through both the lower boulder-clay and the gravels at Killiney, has been noted by many previous observers. Mr. Kilroe considers that the boulder-clay should be regarded as the source of these shells, "and, inferentially, that it, or the materials composing it, were originally laid down on the sea-floor and subsequently pushed up over the land"; and that, from the denudation of this clay, the shells in the gravels have been derived.

The upper boulder-clay of the Killiney section is yellowish and sandy, and in some places contains numerous large blocks of the local granite. It is usually greatly decalcified and oxidised, and,

near Killiney Station, rests upon the truncated edges of sand and gravel beds, here highly inclined. "A short distance south of the station this clay seems to attain a thickness of some 30 feet, which is quite unusual in the entire section or elsewhere in the district. It is probable, therefore, that the top clay merges imperceptibly into one of the layers of the boulder-clay (or several layers combined) which are included in the sand and gravel series; for when these layers occur near the top of the section, they are so highly oxidised and decalcified as to become indistinguishable from the clay which caps the gravels, and for this reason is entitled to the appellation of 'Upper Boulder-clay.'" At many other places in the district a boulder-clay up to 10 or 12 feet in thickness was seen to overlies gravels, but whether this represents the upper clay of the Killiney section could not be determined.

After mentioning and stating objections to the various hypotheses which have been put forward to explain the Irish drifts, and especially their included marine shells and foraminifera in certain localities, Mr. Kilroe writes as follows:—

"Almost the only remaining probable hypothesis is that the materials of the Kill of the Grange clay, and similar clay at other points, has, as already mentioned, been pushed upward as *moraine profonde* from the Irish Sea bed, and if this view be accepted, it at once accounts for the fossil- and stone- contents of the clay and subsequently-deposited gravels. The great obstacle to the acceptance of that hypothesis, of course, is the prevalence of easterly striation—the only direction now noticeable. In its favour, however, it may be mentioned that in coming from the westward it could not have carried the materials of the Kill of the Grange clay; while these materials are exactly such as could have been accumulated on the sea-floor by glaciers descending from the marl plains of Antrim and Down, on the west, and those of the Solway region and Cheshire, probably, on the east, as well as from the glens of Down, Cumberland and Wales, during the approaching climax of glacial conditions. The objection to the material having been subsequently pushed up over Irish land is not insuperable if we conceive that such an accumulation of ice and *névé* occurred in the Cumbro-Cambrian region as, after filling up the Irish Sea, temporarily overmastered any ice-flow coming at the time from Central Ireland, and dragged the sea deposits inward over the present Irish coast line. This westerly flow from Cumberland would become reversed as the Irish ice-system grew, and would unite with an ice-stream flowing southward along the channel, as would also the new easterly ice-flow from Central Ireland. This last, continuing probably for a much longer period than that during which the westerly flow over-rode Irish land, would have obliterated all trace of the latter, except possibly in the spots where the lower boulder-clay occurs, where, however, striae have not been found."

Agricultural Notes.—The prevalence of limestone detritus profoundly affects the character of most of the ground in this

Mr. Kilroe. sheet. The fertility of the soils derived therefrom is manifest in the luxuriant park-timber and hedge-rows, the choice and succulent herbage, which deck the lower portions of the area. The boulder-clay soils and those covering the various deposits of limestone gravels are mostly rich brown loams, which, though in many cases highly retentive, do not manifest great need of artificial drainage.

The alluvial deposits consist of, or yield on weathering, rich sandy loams, bearing a luxuriant herbage, or equally luxuriant crops where tilled, all of which indicate the beneficial effects of occasional saturations of the soils with lime-charged waters, or of top-dressings with flood-silts drawn from limestone, occurring either as solid rock or drifted detritus.

Skirting the small areas of granite in the lower ground, and on the hill slopes below where the granite, slate, &c. protrude above the drift, the soils and sub-soils show a quantity of locally derived material, replacing or concealing the limestone boulder-clays. The soils in those places are poor in comparison with those derived from the limestone detritus, and bear, when not manured, a coarse, unpalatable herbage.

Several samples of soils and sub-soils were taken during the progress of the Survey, and are undergoing examination, the results of which will appear in the Memoir.

Mr. McHenry The area of forty-one square miles surveyed by Mr. McHenry lay almost entirely on the plain in the central part of Sheet 112, and therefore was mainly overspread by the limestone-boulder-clay, though diversified, as already described, in the western part by a fine esker-ridge, and by the valleys of the Liffey and Dodder with their post-glacial fluvial deposits, and also by the low raised beach along its seaward margin. The central part of the city of Dublin is placed on this raised beach, or on the river-deltas conterminous with it, but the higher parts of the city, with most of its suburbs, are built upon the gentle slopes of boulder-clay which border these flats. Although the boulder-clay over the greater parts of the area is of the dark blue limestone-type, there is a marked change of character in certain parts of the mass as we approach the southern margin of the Carboniferous Limestone tract. Thus, in several good sections in the bank of the tributary streams on the southern side of the Dodder Valley between Rathfarnham and Firhouse, a dull purple tenacious clay is exposed, resembling that of the Kill of the Grange brick-pits (above described by Mr. Kilroe). This clay always contains a few fragmentary shells, just as at Kill of the Grange and Killiney, whereas no shells have been found in the normal limestone clay. In one of the stream-sections it was traced southward to Rockbrook, nearly three miles south of the Dodder, sometimes underlying bands of the normal limestone-clay; and it is highly suggestive of the close association of this clay with the shelly stratified drift, that we should find some of the principal exposures of the high-level shell-bearing gravels on the hill-slopes within a mile to the S. and S.E. of this place, and that at Larch Hill a patch of clay of similar character should be actually included in the gravels.

Where the Dodder Valley cuts into the esker-ridge some fine Mr. McHenry sections are exposed along the river-banks.

At this point Mr. McHenry observes that the material of the esker has been entirely derived from the same source as the boulder-clay, the included stones being identical in character, and both showing a notable absence of the Leinster granite, although this local granite is very conspicuous in the late-glacial flood-gravels and subsequent high-level gravels of the Dodder, which rest on eroded surfaces of the esker-gravels in these sections.

Until the investigation has been carried beyond the limits of the present area there is room for uncertainty whether the current which deposited the gravel-ridge flowed northward or southward, but the probability is that it took the latter direction. The occurrence of a water-worn limestone surface beneath the esker, which has been previously mentioned (p. 187), is described by Mr. McHenry as follows:—

“There can be little doubt as to the origin of these gravels and sands. Unquestionably they are due to ice-rivers that flowed both on, in, and in many cases under the ice-sheet. In some cases these ice-rivers cut down through whatever slight covering of boulder-clay there may have been deposited on the solid rock, and washed off the original striae. An instance of this was noticed in the quarry on the west side of the road leading from Green Hills northward, where 20 to 30 feet of gravel is seen resting directly on the Calp limestone, while in the north end of the quarry a thin stratum of boulder-clay rests on the still striated rock-surface, the sand and gravel of the esker resting on the boulder-clay.”

With regard to the Late-glacial Flood-gravels, of which several small tracts were surveyed by him, Mr. McHenry remarks that these bear a close resemblance to the river-gravels both in composition and arrangement though differing in their position in respect to the existing valleys. In most of the places where they occur, both deposits have been extensively worked for building purposes and for pathway material.

The deltas formed where the principal streams open out upon the Raised Beach are necessarily shown on the one-inch map as forming part of this Beach, though sometimes rising slightly above its usual level. They are thus described by Mr. McHenry:—

“Along the shore where the Tolka, the Liffey, and the Dodder enter the sea, extensive fan-shaped deposits of gravel and sand have been laid down. Many extensive openings in them can be seen, the best being those now worked in the vicinity of the main-road to Blackrock, east of the Dodder. For its size, the Dodder appears to have deposited by far the greater proportion of these delta-gravels, this being no doubt due to its rapid fall from the Dublin Hills, causing more violent torrents in early post-glacial times, and to the enormous quantity of glacial material with which its ancient channel was choked.

Mr. McHenry "There is a well-marked feature on both sides of the Liffey which defines the boundary of its river-deposits with the underlying boulder-clay. In all cases, during the excavations for main-drainage purposes, river-gravel was found to exist within the limit of this feature. In almost every instance the river-gravel rests directly upon the boulder-clay, but in a few cases it rests directly on the Carboniferous Limestone, as at the bottom of the new Hawkins Street shaft of the tunnel under the Liffey."

Mr. Seymour. The mountainous ground surveyed by Mr. Seymour on the southern margin of Sheet 112 included the summits of Three Rock (1,479 ft.) and Two Rock (1,699 ft.) Mountains; and Fairy Castle (1,763 ft.) and the lower hills to the westward, with the intervening valleys.

"The deposits of drift are chiefly confined to the valleys, the hilly ground being practically bare granite with a scanty covering of heather and peat. In the Larch Hill and Ticknock valleys, however, the boulder-clay runs up to heights of 1,090 ft. and 950 ft. respectively, the section in the former being 8-10 ft. thick at this elevation and full of striated limestone pebbles and boulders. . . . Kilmarshogue Mountain (1,339 ft.) is almost entirely surrounded by gravel, and the outer boundary of this probably represents the line of a retreating glacier, between the front of which and the mountain slope, the washed morainic material would be deposited as gravel. Some of the steep lower slopes, on which no drift has lodged, are thickly strewn with large boulders of granite, and similar boulders frequently occur in the gravels, especially in their upper part. . . . South of Kilmarshogue is another area of gravels, moundy in places, and reaching a maximum elevation of over 1,300 feet, which have long been noted for the numerous shell-fragments they contain."

A dry gap cutting the ridge on the east side of the Ticknock valley, similar to those at lower levels to the eastward, previously described, is remarked by Mr. Seymour to lie in an almost direct line with the great Montpelier Gap to the westward (in Mr. Wright's ground) and with another still farther west. To explain the much lower elevation attained by the drift on the mountain slopes outside the valleys, Mr. Seymour suggests that the western valleys being of gentle slope without any sharp rise, and lying also in the direction of the ice-flow, as indicated by the striæ, afforded an easy ascent for the drift-laden lower part of the ice, which could not rise upon the bluff slopes of the hill-shoulders.

The tract examined by Mr. Seymour in the N.W. corner of the sheet, forming part of the Carboniferous Limestone plain, is chiefly overspread with limestone-boulder-clay, with some minor kame-like mounds of gravel and protruding ridges of bare or nearly bare rock. The chief interest in this ground centres in the Liffey Valley, which trenches the plain and reveals many good sections in natural and artificial exposures on its steep slopes. It is in this tract that, as previously mentioned, the Liffey apparently diverges from its pre-glacial valley, and cuts a short looped cañon in the solid rock. Near this place the gravelly mounds which are believed to represent the northward

prolongation of the Green Hills Esker, are intercepted by the present valley, and the diversion of the river may possibly have been connected with this circumstance. The easterly portion of the buried pre-glacial channel appears to be filled up chiefly with boulder-clay, as indicated in a deep lateral ravine and in well-borings in the S.W. part of Phoenix Park; but in the western portion there is a thick mass of gravel, which is well seen in pits in the valley below Knockmaroon Lodge. In one of these pits, close to the ferry, numerous shell-fragments were found, associated as usual with far-travelled stones including the Ailsa Craig rock, and with streaks of brown clay. The drifts of the surrounding country appear to be devoid of shells, and no previous record of their occurrence in the Liffey valley is known.

The mapping of the drifts on the peninsula of Howth was undertaken at the beginning of the field-season by Mr. Seymour and Mr. Wright, under the personal guidance of Mr. Lamplugh. It was found that the limestone-clay had practically enwrapped the lower slopes of the hill, though now in part stripped off by later erosion. The curious manner in which this material is "plastered" against the slopes has frequently attracted attention. The summit, however, is principally bare rock, with narrow "tongues" of drift in the hollows between the bosses of quartzite. These bosses are frequently ice-scored, especially on the quartz-veins, where the striae are so fine that they become visible only after the application of some such colouring material as scraped lead-pencil to the smooth greasy-feeling white surface. The striae indicate a general movement of the glaciating agent from about W. 30 N., but swing round the shoulders of the hill, where the ice-current has been deflected. The limestone-clay in the hollows is sometimes covered by a few feet of local detritus, probably in part glacial and in part a later storm-wash, and in some places this material alone is present.

The thick mass of gravel and sand banked against the northern side of the hill at the village of Howth is one of the well-known shell-bearing drift-deposits of the Dublin district, and similar shell fragments also occur sparingly in the patches of boulder-clay on the eastern and southern slopes of the peninsula. The gravels at Howth attain their maximum development opposite a broad depression in the solid rocks, which runs south-eastward nearly across the headland, and they appear to be intimately related to this feature. To the eastward and westward of this hollow the stratified material diminishes rapidly in quantity and in texture, until it appears finally to thin out between an upper and lower band of boulder-clay.

In discussing the upper part of the boulder-clay of these sections Mr. Seymour remarks that it resembles the upper clay which he observed to be similarly associated with gravels in the other areas mapped by him, being less compact than the lower clay and generally found at the foot of more or less steep ascents. "It is almost certainly derived from material either in ice (englacial), or attached to the soles of icebergs: in the first case the material being let down *in situ* by the gradual melting of the

Mr. Seymour.

Mr. Seymour
and
Mr. Wright.

Mr. Seymour
and
Mr. Wright.

ice, and in the second case dropped from melting bergs in lakes." The second explanation appears to him to be the more probable, as the upper clay within the area surveyed by him occurred in places where temporary lakes were likely to be formed during the recession of the ice.

The supposed high-level raised beach near the Bailey Lighthouse, mentioned in the *Survey Memoir* (p. 67), proves to be a "kitchen-midden," containing only edible shells, broken bones of domestic animals, and other indications of artificial accumulation. The only trace of post-glacial marine submergence in this, as in other parts of the district, is the conspicuous Raised Beach of shingle and sand with recent shells, rising 10 to 20 feet above present sea level, which forms the low spit connecting Howth with the mainland. On the rocky outer shores of the headland and of Ireland's Eye, this beach is indicated in places by an eroded rock-shelf and by ancient caves. A cemented mass of old beach-material was observed in one of these caves on Ireland's Eye, adhering to the rock-walls at the usual level of the Raised Beach.

On the mainland west of Howth, the plain of boulder-clay is deeply furrowed by broad drainage hollows, regarding which Mr. Seymour notes: "none of the streamlets now flowing in them could possibly produce such features; they are all 'mis-fits,' and the principal work of erosion must be attributed to a time after the glacial period, when much larger streams flowed through these valleys."

Mr. Wright.

The area surveyed by Mr. Wright in the northern part of Sheet 112, while mainly overspread with the limestone-boulder-clay, was broken in places by outcrops of the solid limestone, and by irregular mounds and short esker-like ridges of stratified drift, the latter being associated, in the vicinity of the Tolka river, with gravelly flats. That these stratified drifts were directly of glacial origin was frequently evident from the manner in which they merged gradually into clayey unstratified material full of scratched stones, which was inseparable from the normal boulder-clay of the district.

In the mountainous ground examined by Mr. Wright in the south-western part of Sheet 112 the drifts were much more complicated, and stratified material was much more abundant. Gravelly deposits, composed principally of limestone, but often with a plentiful admixture of the local granite, and with a few far-transported stones, including Chalk flints, Old Red conglomerate, Silurian grit, and occasionally the Ailsa Craig rock, and where unweathered, with shell-fragments, formed mounded ground on the slopes of the hills up to the 1,250 ft. contour. In descending the slopes these gravels appear usually to pass beneath an upper boulder-clay, though the sections are rarely sufficiently continuous to show this relationship clearly. From one of the high-level gravel pits at Larch Hill no less than forty-two species of shells have been obtained by Mr. Hinch, a persevering amateur student of these shelly deposits.

The fine high-level notch in the solid rock on the southern side of Montpelier Hill, to which reference was made in the introductory part of this report, is described by Mr. Wright as follows:—

“This remarkably steep gap or pass, which is 530 yards long, connects the valleys of Killakee and Glenasmole. Its sides are strewn with blocks of granite, which form a talus at the base, and their slope varies from 20°—35°. The height of the summit is 1035 feet, but it is probably raised considerably above its original height by the falling in of *débris* from the sides. The gap is almost dry, there being only two small rivulets trickling, one from each end, in opposite directions, that on the west being soon joined by a larger stream from the moorland above.

“The gravels associated with this gap form a continuous deposit, lying between the 800 and 1250 ft. contours, which may be roughly divided into an upper and a lower series. The upper series forms a thin covering, with scattered mounds, on the moor overlooking the gap on the south and on Montpelier Hill on the north. The lower series consists of two mounds, one on each side of the valley at the westerly end of the gap. At Ann Mount, in Glenasmole, the gravels also occur at two levels, but the upper level in this case is the same as the lower one in the Montpelier Valley.”

II. MAPS PUBLISHED.

The following is a list of the revised one-inch maps issued by the Geological Survey of Ireland during the past year:—

Sheets Nos. 46, 61, 67, 79, 115, 117, 118, 125, 126, 127, 134, 135, 143.

The revisions are almost wholly confined to the Ordovician and Silurian Rocks.

APPENDIX A.

CATALOGUE of TYPES and FIGURED SPECIMENS of BRITISH FOSSIL PHYLLOCARIDA preserved in the MUSEUM of PRACTICAL GEOLOGY, London.

By H. A. ALLEN, F.G.S.

Each specimen is entered under the name given to it when first figured. When the author's name is placed in brackets, *e.g.* (Phillips), it refers only to the species and not to the genus. The letter **T** indicates that the specimen is the type of the species. The figures in square brackets [7509] correspond to the number in the Museum Register.

The following abbreviations are employed:—

M. G. S.: Memoirs of the Geological Survey of the United Kingdom.

Mon. Pal. Soc.: Monographs of the Palaeontographical Society, London.

Q. J. G. S.: Quarterly Journal of the Geological Society of London.

Geol. Mag.: The Geological Magazine, London.

Caryocaris Marrii, Hicks.

Jones and Woodward, Mon. Pal. Soc., vol. xlv., 1892, pl. xiv., f. 16,
p. 92.
Arenig. [7509] Skiddaw, Cumberland.

Caryocaris Wrightii, Salter.

Jones and Woodward, Mon. Pal. Soc., vol. xlv., 1892, pl. xiv., figs. 11,
12, p. 89.
Skiddaw Slates. [7508, 7509] Skiddaw.

Ceratiocaris aptychoides, *vide* **Dithyrocaris** ?**Ceratiocaris canaliculata**, Jones and Woodward.

Jones and Woodward, Mon. Pal. Soc., vol. xli., 1888, pl. vii., f. 3, p. 32.
Upper Ludlow. [7481] **T.** Whitecliff, Ludlow.

Ceratiocaris cassia, Salter.

Jones and Woodward, Mon. Pal. Soc., vol. xli., 1888, pl. vii., f. 7 c-e, p.
58.
Lower Ludlow. [7451] Trippleton, Leintwardine.

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- Ceratiocaris cassioides**, Jones and Woodward. **T.**
 Jones and Woodward, Mon. Pal. Soc., vol. xli., 1888, pl. vii., f. 6, p. 59.
 Lower Ludlow. [7480] Leintwardine, Shropshire.
- Ceratiocaris gigas** (Salter, M. S.), Jones and Woodward. **T.**
 Jones and Woodward, Mon. Pal. Soc., vol. xli., 1888, pl. iii., f. 1, p. 24.
 Lower Ludlow. [7452] Danefield, Kington, Herefordshire.
- Ceratiocaris halliana**, Jones and Woodward. **T.**
 Jones and Woodward, Mon. Pal. Soc., vol. xli., 1888, pl. ii., figs. 1-4, p. 26.
 Lower Ludlow. [7453-7456] Church Hill, Leintwardine and
 Bow Bridge, Ludlow.
- Ceratiocaris leptodactylus** (McCoy).
 Jones and Woodward, Mon. Pal. Soc., vol. xli., 1888, pl. vi., figs. 6-9,
 p. 14.
 Wenlock Shale (Coniston Grit). [7459, 7855-7857]
 Helm Knot, Dent, Yorkshire.
- Ceratiocaris longa**, Jones and Woodward. **T.**
 Jones and Woodward, Mon. Pal. Soc., vol. xli., 1888, pl. xi., f. 5, p. 43.
 Lower Ludlow. [7468] Leintwardine.
- Ceratiocaris minuta** ? Jones and Woodward. **T.**
 Jones and Woodward, Mon. Pal. Soc., vol. xli., 1888, pl. xi., f. 10, p. 47.
 Lower Ludlow. [7478] Leintwardine.
- Ceratiocaris Murchisoni** (Agassiz).
 Jones and Woodward, Mon. Pal. Soc., vol. xli., 1888, pl. iii., figs. 4, 7,
 p. 16.
 Lower Ludlow. [7473, 7476] Leintwardine.
- Ceratiocaris Murchisoni** (Agassiz). **T.**
 H. Woodward, Geol. Mag., 1866, pl. x., f. 9, p. 203. Refigured as
Ceratiocaris tyrannus: Jones and Woodward, Mon. Pal. Soc.,
 vol. xli., 1888, pl. vi., f. 11, p. 20.
 Wenlock Shale (Coniston Grit). [7472]
 Casterton Low Fell, Kirkby Lonsdale.
- Ceratiocaris papilio**, Salter. **T.**
 J. W. Salter, Ann. Mag. Nat. Hist., vol. v., 1860, p. 154, f. 1.
 Lower Ludlow. [7479] Logan Water, Lesmahagow.
- Ceratiocaris reticosa**, Jones and Woodward. **T.**
 Jones and Woodward, Geol. Mag., 1895, pl. xv., f. 1 *a, b*, p. 539.
 Ludlow. [4435] Locality ?
- Ceratiocaris robusta**, Salter.
 Jones and Woodward, Mon. Pal. Soc., vol. xli., 1888, pl. x., f. 10, p. 44.
 Lower Ludlow. [7471] Leintwardine.
- Ceratiocaris salteriana**, Jones and Woodward. **T.**
 Jones and Woodward, Mon. Pal. Soc., vol. xli., 1888, pl. vii., f. 1 *a, b*,
 p. 55.
 Lower Ludlow. [7477] Bow Bridge, Ludlow.
- Ceratiocaris solenoides**, McCoy.
 Jones and Woodward, Mon. Pal. Soc., vol. xli., 1888, pl. viii., f. 9 *a, b*,
 p. 52.
 Upper Ludlow. [7458] Benson Knot, Kendal.

Ceratiocaris stygia, Salter.

Jones and Woodward, Mon. Pal. Soc., vol. xli., 1888, pl. xi., f. 3, p. 38.
Lower Ludlow. [7469] Leintwardine.

Ceratiocaris tyrannus (Salter, M. S.), Jones and Woodward. **T.**

Jones and Woodward, Mon. Pal. Soc., vol. xli., 1888, pl. iii., figs. 2, 3, 5, 8,
p. 22. (See also *C. murchisoni*.)
Lower Ludlow. [7474, 7475] Leintwardine.

Dictyocaris Ramsayi, Salter. **T.**

J. W. Salter, M. G. S., Edinburgh, 1861, pl. ii., f. 20, p. 133.
Salter and Woodward, Chart Foss. Crust., 1865, p. 17.
Upper Silurian. [7483] North Esk Reservoir, Carlups.

Dithyrocaris Colei, Portlock. **T.**

J. E. Portlock, Rep. Geol. Londonderry, 1843, pl. xii., figs. 1-5, p. 314.
Jones and Woodward, Mon. Pal. Soc., vol. lii., 1898, pl. xxiii., figs. 2-5 ;
pl. xxiv., figs. 2, 4, p. 163.
Carboniferous Shales. [6261-6263, 6265] Clogher, Tyrone.
Jones and Woodward, Mon. Pal. Soc., vol. lii., 1898, pl. xxvii., f. 5,
p. 168.
Carboniferous Shales. [6260] Clogher, Tyrone.
J. E. Portlock, Rep. Geol. Londonderry, 1843, pl. xii., f. 6, p. 315.
H. Woodward, Geol. Mag., 1865, pl. xi., f. 8, p. 401.
Jones and Woodward, Mon. Pal. Soc., vol. lii., 1898, pl. xxvi., f. 44,
p. 194.
Carboniferous Shales. [6264] Co. Derry.

Dithyrocaris orbicularis, Portlock. **T.**

J. E. Portlock, Rep. Geol. Londonderry, 1843, p. 316.
Jones and Woodward, Mon. Pal. Soc., vol. lii., 1898, pl. xxiv., f. 3, p. 168.
Lower Carboniferous. [6266] White Water River, Co. Derry.

Dithyrocaris testudinea (Scouler).

Jones and Woodward, Mon. Pal. Soc., vol. lii., 1898, pl. xix., f. 9, p. 145.
Lower Carboniferous. [6268] Glasgow Coalfield.

Dithyrocaris tricornis (Scouler).

Jones and Woodward, Mon. Pal. Soc., vol. lii., 1898, pl. xxvii., f. 2 a-c,
p. 170.
Lower Carboniferous. [7519] East Kilbride, Lanarkshire.

Dithyrocaris ? aptychoides, Salter. **T.**

J. W. Salter, Q. J. G. S., vol. viii., 1852, pl. xxi., f. 10, p. 391. Described
as *Ceratiocaris aptychoides*, J. W. Salter, Ann. Mag. Nat. Hist.,
vol. v., 1860, p. 161 ; and as *Peltocaris aptychoides*, Salter, Q. J. G. S.,
vol. xix., 1863, p. 88 (text figure) ; Jones and Woodward, Mon.
Pal. Soc., vol. xlvi., 1892, pl. xvi., f. 3, p. 113.
Llandeilo Flags. [7507] Duff Kennel, Dumfriesshire.

Emmelezoe crassistriata, Jones and Woodward. **T.**

Jones and Woodward, Mon. Pal. Soc., vol. xli., 1888, pl. viii., f. 3, p. 70.
Upper Ludlow. [7457] Combe Wood, Presteign.

Emmelezoe maccoyana, Jones and Woodward. **T.**

Jones and Woodward, Mon. Pal. Soc., vol. xli., 1888, pl. viii., f. 2, p. 71.
Lower Ludlow. [7470] Leintwardine.

Hymenocaris vermicanda, Salter.**T.**

J. W. Salter, M. G. S., North Wales, 1866, pl. ii., figs. 1, 2, p. 293.
 Lower Lingula Flags. [7502] Penmorfa, Tremadoc.

J. W. Salter, M. G. S., North Wales, 1866, pl. v., f. 25, p. 293.

Jones and Woodward, Mon. Pal. Soc., vol. xlv., 1892, pl. xiii., f. 9, p. 74.
 Lower Lingula Flags. [7503] Moel-y-gest, Tremadoc.

Hymenocaris vermicanda, Salter.

Jones and Woodward, Mon. Pal. Soc., vol. xlv., 1892, pl. xiii., figs. 8,
 13, p. 74.
 Lingula Flags. [7505, 7504] Portmadoc.

Hymenocaris vermicanda ? (tracks of).

J. W. Salter, Q. J. G. S., vol. x., 1853, p. 210. (Text figure.)

J. W. Salter, M. G. S., North Wales, 1866, pl. i., p. 294.
 Lower Lingula Flags. [7520] Tremadoc, N Wales.

Lingulocaris lingulæcomes, Salter.

Jones and Woodward, Mon. Pal. Soc., vol. xlv., 1892, pl. xiv., f. 4, p. 81.
 Upper Llandeilo. [7510] Bwlth.

Peltocaris anatina, Jones and Woodward.

Jones and Woodward, Mon. Pal. Soc., vol. xlv., 1892, pl. xvi., f. 4, p. 114.
 Llandeilo Flags. [7506] Moffat ?

Peltocaris aptychoides, *vide* **Dithyrocaris** ?**Peltocaris** ? (tracks of).

J. W. Salter, Q. J. G. S., vol. xix., 1863, p. 94. (Text figure.)
 Llandeilo Flags. [7521] Wilmington Dingle, Chirbury, Salop.

Salterina [**Salterella**] **pholadiformis** (Salter, M. S.), Jones and Woodward.**T.**

Jones and Woodward, Geol. Mag., 1888, p. 453. (Text figure.)
 Lower Limestone Shales. [7518] Berwick-on-Tweed.

APPENDIX B.

CATALOGUE of TYPES and FIGURED SPECIMENS of BRITISH
PALÆOZOIC ECHINODERMATA preserved in the MUSEUM of
PRACTICAL GEOLOGY, London.

By H. A. ALLEN, F.G.S.

Each specimen is entered under the name given to it when first figured. When the author's name is placed in brackets, *e.g.* (Phillips), it refers only to the species and not to the genus. The letter **T** indicates that the specimen is the type of the species. The figures in square brackets [7009] correspond to the number in the Museum Register.

The following abbreviations are employed:—

- M. G. S.: Memoirs of the Geological Survey of the United Kingdom.
 Mon. Pal. Soc.: Monographs of the Palæontographical Society, London.
 Pal. Foss.: Figures and Descriptions of the Palæozoic Fossils of Cornwall, Devon, and West Somerset, by John Phillips, 1841.
 Q. J. G. S.: Quarterly Journal of the Geological Society of London.
 Geol. Mag.: The Geological Magazine, London.

CYSTIDEA.

Caryocystites granatum (Wahlenberg).

E. Forbes, M. G. S., vol. ii., pt. 2, 1848, pl. xxi., f. 4, p. 512.
 Caradoc. [7406] Rhiwlas, Bala.

Caryocystites Litchi, Forbes.

E. Forbes, M. G. S., vol. ii., pt. 2, 1848, pl. xxi., f. 2 *a-c*, p. 514. Re-
 figured as **Sphæronites Litchi**: J. W. Salter, M. G. S., North Wales,
 1866, pl. xx., figs. 3 & 4, p. 286. (Figs. 3 and 4 *c* referred to *S.*
munitus.)
 Caradoc. [7431] Sholeshook, Haverfordwest.

Caryocystites ? munitus, Forbes.**T.**

E. Forbes, M. G. S., vol. ii., pt. 2, 1848, pl. xxi., f. 3 *a, b*, p. 515. Re-
 figured as **Sphæronites munitus**: J. W. Salter, M. G. S., North
 Wales, 1866, pl. xx., f. 5, p. 285.
 Caradoc. [7429] Rhiwlas, Bala.

Caryocystites pyriformis, Forbes.**T.**

E. Forbes, M. G. S., vol. ii., pt. 2, 1848, pl. xxi., f. 1 *a-d*, p. 515. Re-
 figured as **Sphæronites pyriformis**: J. W. Salter, M. G. S., North
 Wales, 1866, pl. xx., figs. 1, 2, p. 285.
 Caradoc. [7432] Rhiwlas, Bala.

GEOL. SURVEY. SUMMARY OF PROGRESS FOR 1901.

- Echinocystites pomum**, W. Thomson. T.
Wyville Thomson, Edin. New Phil. Journ., N. S., vol. xiii., 1861, pl. i.,
f. 3, p. 109.
Lower Ludlow. [7385] Leintwardine.
- Echinoencrinites armatus**, Forbes. T.
E. Forbes, Mem. Geol. Survey, vol. ii., pt. 2, 1848, pl. xviii., figs. 1-6,
11-13; pl. xix., figs. 1, 4, 6, p. 507.
Wenlock Limestone. [7381-4] Walsall.
- Echinoencrinites baccatus**, Forbes. T.
E. Forbes, M. G. S., vol. ii., pt. 2, 1848, pl. xvii., figs. 1, 3, 4, p. 506.
Wenlock Limestone. [7380] Walsall.
- Echinosphærites arachnoideus**, *vide* **Sphæronites**.
- Hemicosmites oblongus**, (Pander).
E. Forbes, M. G. S., vol. ii., pt. 2, 1848, pl. xx., f. 6, p. 511.
J. W. Salter, M. G. S., North Wales, 1866, pl. xx., f. 11, p. 288.
Caradoc. [7426] Sholeshook, Haverfordwest.
- Hemicosmites pyriformis**, v. Buch.
E. Forbes, M. G. S., vol. ii., pt. 2, 1848, pl. xx., figs. 2-5, p. 511. Re-
figured as **H. rugatus**, Forbes: J. W. Salter, M. G. S., North Wales,
1866, pl. xx., f. 12, p. 288.
Caradoc. [7421, 7422] Gt. Cresswell, St. Clare; Sholeshook.
- Hemicosmites rugatus**, *vide* **H. pyriformis**.
- Pleurocystites Rugeri**, Salter. T.
J. W. Salter, M. G. S., North Wales, 1866, pl. xxiii., f. 5, p. 288.
Caradoc. [7434] Blaen-y-cwm, nr. Llandovery.
- Sphæronites arachnoideus**, Forbes. T.
E. Forbes, M. G. S., vol. ii., pt. 2, 1848, pl. xxii., f. 4, p. 518. Refigured
as **Echinosphærites**: J. W. Salter, M. G. S., North Wales, 1866, pl.
xx., f. 8, p. 287.
Caradoc. [7405] Sholeshook, Haverfordwest.
- Sphæronites aurantium** (Gyllenhal).
E. Forbes, M. G. S., vol. ii., pt. 2, 1848, pl. xxii., f. 1 *a, b*, p. 516. Fig.
1 *b* refigured as **S. stelluliferus**: J. W. Salter, M. G. S., North
Wales, 1866, pl. xx., f. 6, p. 287.
Caradoc. [7428] Sholeshook, Haverfordwest.
- Sphæronites Litchi**, *vide* **Caryocystites**.
- Sphæronites munitus** ? Forbes.
J. W. Salter, M. G. S., North Wales, 1866, pl. xx., figs. 3, 4 *c*, p. 286.
Caradoc. (See also *Caryocystites*.) [7430] Sholeshook, Pembrokeshire.
- Sphæronites ? punctatus**, Forbes. T.
E. Forbes, M. G. S., vol. ii., pt. 2, 1848, pl. xxii., f. 2 *a, b*, p. 518.
J. W. Salter, M. G. S., North Wales, 1866, pl. xx., f. 7, p. 286.
Caradoc. [7433] Rhiwlas, Bala.
- Sphæronites pyriformis**, *vide* **Caryocystites**.
- Sphæronites stelluliferus**, *vide* **S. aurantium**.

CRINOIDEA.

Actinocrinites amphora, (Goldfuss).

J. E. Portlock, Rep. Geol. Londonderry, 1843, pl. xv., figs. 4 *a*, *b*, 5 *a*, *b*
p. 347.

Carboniferous Limestone. [7615] Cleenish, Tonymoman, Fermanagh.

Actinocrinus ? Batheri, Whidborne.

T.

G. F. Whidborne, Mon. Pal. Soc., 1898, vol. lii., pl. xxxii., figs. 2, 2 *a*, *b*,
3, 3 *a*, *b*, p. 222.

Upper Devonian (Marwood Beds). [7145, 7146] Braunton, North Devon.

Actinocrinites decadactylus ? Goldfuss.

J. E. Portlock, Rep. Geol. Londonderry, 1843, p. 349.

Carboniferous Limestone. [7629] Stewartstown, Tyrone.

Actinocrinites icosidactylus, Portlock.

T.

J. E. Portlock, Rep. Geol. Londonderry, 1843, pl. xv., f. 7, p. 348.

Carboniferous Limestone. [7628] Hook, Wexford.

Actinocrinus Porteri, Whidborne.

T.

G. F. Whidborne, Mon. Pal. Soc., vol. lii., 1898, pl. xxxi., figs. 1, 1 *a*
2, 5 ; pl. xxxii., f. 1, p. 220.

Upper Devonian. [7138-7141] North Devon.

Actinocrinites ? retarius, Phillips.

T.

R. I. Murchison, "Silurian System," pt. 2, 1837, pl. xvii., f. 7, p. 674.

Wenlock Limestone. [7379] Dudley.

Adelocrinus hystrix, Phillips.

T.

J. Phillips, Pal. Foss., 1841, pl. xvi., f. 42 *a*, *b*, p. 30.

G. F. Whidborne, Mon. Pal. Soc., vol. lii., 1898, pl. xxx., f. 4, p. 224.

Upper Devonian (Pilton Beds). [7157] Brushford, N. Devon.

G. F. Whidborne, Mon. Pal. Soc., vol. lii., 1898, pl. xxx., figs. 7, 7*a*, p. 224.

Upper Devonian (Pilton Beds). [7156] Braunton.

Crinoid, Auxiliary arm of

J. E. Portlock, Rep. Geol. Londonderry, 1843, pl. xv., f. 3, p. 346.

Caradoc. [7390] Desertcreat, Tyrone.

Crinoidal Column.

J. E. Portlock, Rep. Geol. Londonderry, 1843, pl. xv., f. 2 *a*, *b*, p. 345.

Caradoc. [7392] Desertcreat, Tyrone.

Capressocrinus crassus, Goldfuss.

G. F. Whidborne, Mon. Pal. Soc., vol. xlix., 1895, pl. xxiv., figs. 4, 4 *a*,
p. 207.

Middle Devonian. [7087] Newton Bushel.

Cyathocrinus acinotubus ? Angelin.

F. A. Bather, Ann. Mag. Nat. Hist., vol. ix., 1892, p. 211. (Text figure 5.)

Wenlock Limestone. [7375] Dudley.

Cyathocrinus ? ellipticus, Phillips.

T.

J. Phillips, Pal. Foss., 1841, pl. xvi., f. 49 *a-d*, p. 32.

Upper Devonian. [7147] Petherwin, Cornwall.

Cyathocrinus ? macrodactylus, Phillips,

T.

J. Phillips, Pal. Foss., pl. xv., f. 41*e*, p. 29. Refigured as **Taxocrinus**
macrodactylus: G. F. Whidborne, Mon. Pal. Soc., vol. lii., 1898, pl.
xxxiii., f. 2, p. 215.

Upper Devonian (Pilton Beds). [7148] Pilton, North Devon.

Gilbertsocrinus simplex, Portlock.**T.**

J. E. Portlock, Rep. Geol. Londonderry, 1843, pl. xvi., f. 5 *a, b*, p. 351.
Carboniferous Limestone. [7615] Fermanagh.

Glyptocrinus ? (Cœlocrinus) basalis, M'Coy.

J. W. Salter, M. G. S., Geol. North Wales, 1866, pl. xxiii., f. 4, 4 *a*, p. 283.
Caradoc. [7388] Guilsfield, near Meifod.

J. W. Salter, M. G. S., Geol. North Wales, 1866, pl. xxiii., f. 4 *b*, p. 283.
Caradoc. [7389] Gwreiddian, Llanwddyn.

Hexacrinus depressus, Austin.**T.**

T. and T. Austin, "Recent and Fossil Crinoidea," 1843, pl. vi., f. 2*a-c*, p. 49.
Middle Devonian. [7089, 7091] Newton Bushel.

Hexacrinus interscapularis (Phillips).

G. F. Whidborne, Mon. Pal. Soc., vol. xlix., 1895, pl. xxi., f. 2 ; pl. xxii.,
figs. 2, 2 *a*, p. 190. (See also *Platycrinus interscapularis*.)
Middle Devonian. [1549, 7090] Bradley and Newton Abbot.

Hexacrinus macrotatus, Austin.**T.**

T. and T. Austin, "Rec. and Foss. Crinoidea," 1843, pl. vi., f. 3 *a, d*, p. 50.
G. F. Whidborne, Mon. Pal. Soc., vol. xlix., 1895, pl. xxii., f. 6, p. 192.
(See also *Platycrinus tuberculatus*.)
Middle Devonian. [6880] Newton Bushel.

Hexacrinus melo, *vide* **Platycrinus interscapularis**.**Hexacrinus ? pentangularis**, Austin.**T.**

T. and T. Austin, "Rec. and Foss. Crinoidea," 1843, pl. vii., f. 1 *a-c*, p. 51.
Refigured as **Hexacrinus quintangulus**, G. F. Whidborne, Mon.
Pal. Soc., vol. xlix., 1895, pl. xxiii., figs. 6, 6 *a, b*, p. 198.
Middle Devonian. [7095] Newton Bushel.

Hexacrinus perarmatus, Whidborne.**T.**

G. F. Whidborne, Mon. Pal. Soc., vol. xlix., 1895, pl. xxii., f. 10, p. 194.
Middle Devonian. [6879] Newton Bushel.

Hexacrinus quintangulus, *vide* **Hexacrinus ? pentangularis**.**Hexacrinus Vicarii**, Whidborne.**T.**

G. F. Whidborne, Mon. Pal. Soc., vol. xlix., 1895, pl. xxiii., f. 4, p. 197.
(See also *Platycrinus pentangularis ?*.)
Middle Devonian. [7093] Newton Bushel.

Hydreionocrinus ? globularis, de Koninck.**T.**

L. de Koninck, Bull. Acad. Roy. Bruxelles, ser. 2, t. iv., 1858, pl. ii.,
figs. 1-4, p. 93. "The Geologist," vol. i., 1858, pl. iv., figs. 1-4, p. 180.
Carboniferous Limestone (*Productus*-bed). [7440] Lesmahagow.

Hydreionocrinus scoticus, de Koninck.**T.**

L. de Koninck, Bull. Acad. Roy. Bruxelles, ser. 2, t. iv., 1858, pl. ii.,
figs. 6, 7 ; p. 93. "The Geologist," vol. i., 1858, pl. iv., f. 6, 7, p. 179.
Carboniferous Limestone (*Productus*-bed). [7439] Lesmahagow.

Platycrinus granulatus, Miller.

T. and T. Austin, "Rec. and Foss. Crinoidea," 1843, pl. iii., f. 2 *m*, p. 33.
Carboniferous Limestone. [7630] Hook Point, Wexford.

Platycrinites granulatus, Miller.

J. E. Portlock, Rep. Geol. Londonderry, 1843, pl. xvi., f. 4, p. 350.
Carboniferous Limestone. [7631] Hook Point, Wexford.

Platycrinus interscapularis, Phillips.**T.**

J. Phillips, Pal. Foss., pl. xiv., f. 39 *a-d*, p. 28. Refigured as **Hexacrinus melo**, Austin, T. "Rec. and Foss. Crinoidea," 1843, pl. vi., f. 1 *a-e*, p. 48; and as **Hexacrinus interscapularis**: G. F. Whidborne, Mon. Pal. Soc., vol. xlix., 1895, pl. xxi., figs. 1, 1 *a-d*, p. 190.

Middle Devonian.

[7088] Newton Bushel.

Platycrinites lævis, Miller.

T. and T. Austin, "Rec. and Foss. Crinoidea," 1843, pl. i., f. 1 *d, e, f, i, l, n*, p. 8.

Carboniferous Limestone.

[7632-7634]

Hook Point, Wexford.

Platycrinus pentangularis? Phillips.

J. Phillips, Pal. Foss., pl. lx., f. 29**, p. 135. Refigured as **Hexacrinus Vicarii**, G. F. Whidborne, Mon. Pal. Soc., vol. xlix., 1895, pl. xxiii., f. 5, p. 197.

Middle Devonian.

[7092, 7093]

Newton Bushel.

Platycrinites spinosus, Austin.**T.**

T. and T. Austin, "Rec. and Foss. Crinoidea," 1843, pl. i., f. 2 *p, q*, p. 19.

Carboniferous Limestone.

[7663]

Hook Point, Wexford.

Platycrinites trigintidactylus, Austin.**T.**

T. and T. Austin, "Rec. and Foss. Crinoidea," 1843, pl. iii., f. 1 *b*, p. 30.

Carboniferous Limestone.

[7664]

Hook Point, Wexford.

Platycrinus tuberculatus? Phillips.

J. Phillips, Pal. Foss., pl. lx., f. 39,* p. 134. Refigured as **Hexacrinus macrotatus**, Austin, T., "Rec. and Foss. Crinoidea," 1843, pl. vi., f. 3 *b*, p. 50; G. F. Whidborne, Mon. Pal. Soc., vol. xlix., 1895, pl. xxii., f. 8, p. 192.

Middle Devonian.

[7094]

Newton Bushel.

Poteriocrinus conicus, Phillips.

T. and T. Austin, "Rec. and Foss. Crinoidea," 1843, pl. x., f. 3 *c*, p. 82.

Carboniferous.

[7606]

Clifton, Bristol.

J. E. Portlock, Rep. Geol. Londonderry, 1843, pl. xvi., f. 12, p. 350.

Carboniferous.

[7602]

Fermanagh.

Poteriocrinus dactyloides, Austin.**T.**

T. and T. Austin, "Rec. and Foss. Crinoidea," 1843, pl. x., f. 7, p. 85.

Carboniferous Limestone.

[7604]

Hook Point, Wexford.

Poteriocrinus isacobus, Austin.**T.**

T. and T. Austin, "Rec. and Foss. Crinoidea," 1843, pl. viii., f. 4 *a-d*, p. 74.

Carboniferous Limestone.

[7605]

Hook Point, Wexford.

Poteriocrinus latifrons, Austin.**T.**

T. and T. Austin, "Rec. and Foss. Crinoidea," 1843, pl. x., f. 4, p. 82.

Carboniferous Limestone.

[7603]

Mendip Hills.

Poteriocrinus quinquangularis, Austin.**T.**

T. and T. Austin, "Rec. and Foss. Crinoidea," 1843, pl. x., f. 2 *a-e*, p. 80.

Carboniferous Limestone.

[7608-7611]

Hook Point, Wexford.

Poteriocrinus radiatus, Austin.**T.**

T. and T. Austin, "Rec. and Foss. Crinoidea," 1843, pl. x., f. 1 *a, b*, p. 79.

Carboniferous Limestone.

[7614]

Hook Point, Wexford.

Poteriocrinus rostratus, Austin.**T.**

T. and T. Austin, "Rec. and Foss. Crinoidea," 1843, pl. ix., f. 2 *b*, c, p. 75.
Carboniferous Limestone. [7613, 7612] Hook Point, Wexford.

Poteriocrinus sp.

G. F. Whidborne, Mon. Pal. Soc., vol. lii., 1898, pl. xxxv., f. 4, p. 228.
Upper Devonian (Marwood Beds). [7155] Braunton Down, N. Devon.

Poteriocrinus sp.

G. F. Whidborne, Mon. Pal. Soc., vol. lii., 1898, pl. xxxvi., figs. 9, 9 *a*,
p. 228.
Upper Devonian (Marwood Beds). [7155] Braunton Down, N. Devon.

Rhodocrinus (Acanthocrinus) sp.

G. F. Whidborne, Mon. Pal. Soc., vol. xlix., 1895, pl. xxiv., figs. 6, 6 *a*,
p. 204.
Middle Devonian. [7096] Newton Bushel.

Rhodocrinus ?

G. F. Whidborne, Mon. Pal. Soc., vol. lii., 1898, pl. xxxi., f. 3 *a-d*, p. 217.
Upper Devonian (Marwood Beds). [7142, 7143] North Devon.

Scaphiocrinus ? inordinatus ? Whidborne.

G. F. Whidborne, Mon. Pal. Soc., vol. lii., 1898, pl. xxxiv., f. 7, p. 230.
Upper Devonian (Marwood Beds). [7151] Braunton, North Devon.

Scaphiocrinus ? plumifer, Whidborne.**T.**

G. F. Whidborne, Mon. Pal. Soc., vol. lii., 1898, pl. xxxvi., figs. 1, 1 *a*,
p. 228.
Upper Devonian (Marwood Beds). [7153] Braunton, North Devon.

Scaphiocrinus sp.

G. F. Whidborne, Mon. Pal. Soc., vol. lii., 1898, pl. xxxiv., figs. 8, 8 *a*,
p. 231.
Upper Devonian (Marwood Beds). [7152] Braunton, North Devon.

Sphærocrinus geometricus (Goldfuss).

G. F. Whidborne, Mon. Pal. Soc., vol. xlix., 1895, pl. xxiv., f. 8, p. 211.
Middle Devonian. [6878] Newton Bushel.

Taxocrinus macrodactylus (Phillips).

G. F. Whidborne, Mon. Pal. Soc., vol. lii., 1898, pl. xxxiii., figs. 3, 3*a*, 4,
4*a*, p. 215. (See also *Cyathocrinus* ?).
Upper Devonian (Marwood Beds). [7149, 7150] North Devon.

Trochocrinites lævis, Portlock.**T.**

J. E. Portlock, Rep. Geol. Londonderry, 1843, pl. xv., f. 1, p. 345.
Caradoc. [7391] Desertcreat, Tyrone.

EDRIOASTEROIDEA.

Agelacrinites buchianus, Forbes.**T.**

E. Forbes, M. G. S., vol. ii., pt. 2, 1848, pl. xxiii., figs. 1-14, p. 521.
Figs. 2 and 3 refigured, J. W. Salter, M. G. S., Geol. North Wales,
1866, pl. xx., f. 13, p. 291. Figs. 1-9 refigured as **Edrioaster**, F. A.
Bather, Geol. Mag., 1900, plates viii-x. and text figures, pp. 193-204.
Fig. 1 refigured, O. Jaekel, "Stammesgeschichte der Pelmatozoen,"
vol. i., 1899, p. 45 (text figure).
Caradoc. [7403, 7404] 2 mls. W. of Yspetty Evan, Denbighshire.

P

Edrioaster, *vide* **Agelacrinites**.

Lepidodiscus Milleri, Sharman and Newton.

T.

G. Sharman and E. T. Newton, Q. J. G. S., vol. xlviii., 1892, pl. ii.,
p. 150.
Carboniferous Limestone. [7662] River Irthing, Cumberland.

ASTEROIDEA.

Asterias primæva, Salter. *Vide* **Palæaster obtusus**.

Eugaster ? perarmatus (Whidborne).

T.

G. F. Whidborne, Mon. Pal. Soc., vol. lii., 1898, pl. xxvii., figs. 6, 6 a,
p. 209.
Upper Devonian (Pilton Beds). [7163] Branton Down.

Palæaster asperrimus, Salter.

T.

J. W. Salter, Ann. Mag. Nat. Hist., vol. xx., 1857, p. 325.
J. W. Salter, M. G. S., North Wales, 1866, pl. xxiii., f. 2, p. 289.
Caradoc. [7435] Quakers' Burial Ground, Welshpool.

Palæaster coronella, Salter.

T.

J. W. Salter, Ann. Mag. Nat. Hist., vol. xx., 1857, p. 326.
Upper Llandovery. [7402] Gunwick Hill, Malvern.

Palæaster longimanus, Whidborne.

T.

G. F. Whidborne, Mon. Pal. Soc., vol. lii., 1898, pl. xxvi., figs. 1, 1 a, 2,
3, 3 a, b, p. 204.
Upper Devonian (Pilton Beds). [7162-7164]
Park near Branton, and Baggy Point, North Devon.

Palæaster (Uraster) obtusus, Forbes.

J. W. Salter, Ann. Mag. Nat. Hist., vol. xx., 1857, p. 326.
J. W. Salter, M. G. S., North Wales, 1866, pl. xxiii., f. 1, p. 289.
Caradoc. (See also *Uraster*.) [7436] Moel-y-Garnedd.

Protaster granifer (Whidborne).

T.

G. F. Whidborne, Mon. Pal. Soc., vol. lii., 1898, pl. xxvi., figs. 5, 5 a, 6,
6 a, p. 207.
Upper Devonian (Pilton Beds). [7165, 7166] North Devon.

Protaster ? (Drepanaster) scabrosus, Whidborne, var.

T.

G. F. Whidborne, Mon. Pal. Soc., vol. lii., 1898, pl. xxviii., figs. 1, 1 a, b,
2, 2 a, b, p. 208.
Upper Devonian. [7167, 7168] Croyde, N. Devon.
G. F. Whidborne, Mon. Pal. Soc., 1898, pl. xxix., figs. 2, 2 a, p. 208.
Upper Devonian (Pilton Beds). [7169] Branton Down, N. Devon.

Uraster obtusus, Forbes.

T.

E. Forbes, M. G. S., vol. ii., pt. 2, 1848, p. 463.
E. Forbes, M. G. S., Decade 1, 1849, pl. 1, f. 3, p. 2.
Caradoc. (See also *Palæaster*.) [7437] Waterford.

OPHIUROIDEA.

Ophiurella ? gregaria (Whidborne).

T.

G. F. Whidborne, Mon. Pal. Soc., lii., 1898, pl. xxviii., f. 3, p. 210.
Upper Devonian (Pilton Beds). [7162] Branton Down, N. Devon.

ECHINOIDEA.

Cidaris benburbensis, Portlock.

T

J. E. Portlock, Rep. Geol. Londonderry, 1843, pl. xvi., figs. 10, 10 *a*, *b*, 11, p. 352.

Carboniferous Limestone.

[7659]

Benburb, Tyrone.

Protocidaris acuaria (Whidborne).

T.

G. F. Whidborne, Mon. Pal. Soc., vol. lii., 1898, pl. xxv., figs. 1, 1 *a*, *b*, 2, 2 *a*, p. 203.

Upper Devonian (Pilton Beds).

[7158, 7159]

East of Barnstaple.

Lepidesthes ? devonicans, Whidborne.

T.

G. F. Whidborne, Mon. Pal. Soc., vol. lii., 1898, pl. xxiv., figs. 1, 2 ; pl. xxv., f. 3 *a-f*, p. 200.

Upper Devonian (Pilton Beds).

[7160, 7161]

East of Barnstaple.

Melonites Etheridgii, Keeping.

T.

W. Keeping, Q. J. G. S., vol. xxxii., 1876, figs. 1-6, p. 397.

Carboniferous Limestone.

[6577]

Clitheroe.

Palæchinus gigas, McCoy.

R. T. Jackson, Bull. Geol. Soc. America, vol. vii., 1896, pl. vii., figs. 38, 39, p. 204.

Carboniferous Limestone.

[6576]

Clitheroe, Lancashire.

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